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EFFECTS OF WING AND NACELLE MODIFICATIONS ON

DRAG AND WAKE CHARACTERISTICS OF A

BOMBER-TYPE AIRPLANE MODEL

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EFFECTS OF WING AND NACELLE MODIFICATIONS ON

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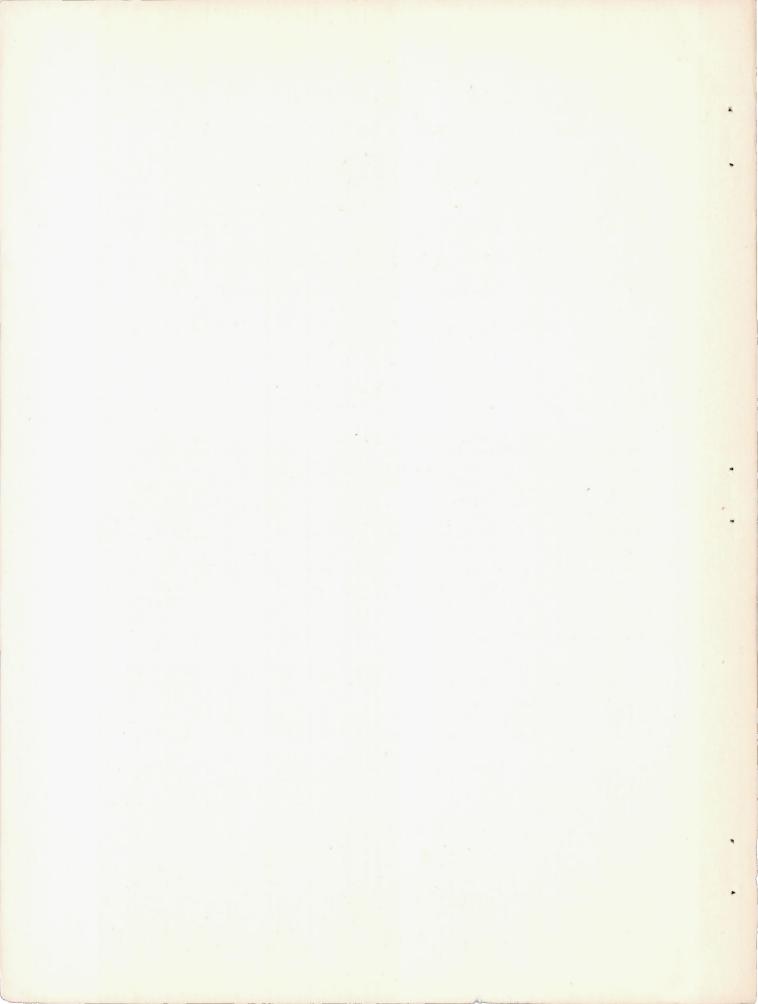By Robert H. Neely, Richard W. Fairbanks
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S U M M A R Y

    An investigation of a model of a large four-engine
bomber was conducted in the Langley 19-foot pressure
tunnel to determine the effects of several wing and
nacelle modifications on drag characteristics and air-
flow characteristics at the tail. Leading-edge gloves,
trailing-edge extensions, and modified nacelle afterbodies
were tested individually and in combination. The effects
of the various modifications were determined by force
tests, tuft observations, and turbulence surveys in the
region of the tail. Tests were made with fixed and
natural transition on the wing and with propellers oper-
ating and propellers off. Most of the tests were con-
ducted at a Reynolds number of approximately 2.6×10^6.

    The results indicated that application of certain
of the modifications provided worth-while improvements
in the characteristics of the model. The flow over the
wing and flaps was improved, the drag was reduced, and
the turbulence in the region of the tail was reduced.

    Trailing-edge extensions were the most effective
individual modification in improving the flow over the
wing with wing flaps neutral, cowl and intercooler flaps
closed. Modified nacelle afterbodies were the most
effective individual modification in reducing drag with
either fixed or natural transition on the wing; however,
trailing-edge extensions were slightly more effective
with fixed transition. Combinations of either leading-
or trailing-edge extensions and modified afterbodies were
more effective than either modification alone. With cowl
and intercooler flaps open, trailing-edge extensions with
modified afterbodies provided substantial improvement in

flow and drag characteristics. With wing flaps deflected,
enclosing the flap behind the inboard nacelle within an
extended afterbody or cutting the flaps at the nacelle
appeared to be the most promising methods of improving
the flow over the flaps and the tail. Although the
results of hot-wire-anemometer surveys were not conclusive
in regard to buffeting characteristics, the modifications
did reduce the turbulence at the tail with wing flaps
both neutral and deflected. The modifications, as a rule,
were favorable to maximum lift. Appreciable reductions
in longitudinal stability of the model were caused by
addition of leading-edge gloves and trailing-edge
extensions.

INTRODUCTION

Separation of flow over a wing increases the drag
and has, in a number of instances, caused tail buffeting
because of the irregular nature of the flow at the tail.
Several wing and nacelle modifications, designed with a
view to improving the flow over the wing, were tested on a
model of a large four-engine bomber to determine the
effects on drag characteristics and air-flow character-
istics at the tail. Leading-edge gloves, wing trailing-
edge extensions, and modified nacelle afterbodies were
tested. The characteristics of the basic and modified
model were determined by tuft observations, force meas-
urements, and measurements of turbulence and dynamic
pressure in the vicinity of the tail. Turbulence was
measured by means of a hot-wire anemometer. The hot-wire-
anemometer equipment was furnished by the California
Institute of Technology and was operated under the direc-
tion of Dr. Hans W. Liepmann of its staff. The investiga-
tion was conducted in the Langley 19-foot pressure tunnel.

SYMBOLS

The coefficients and symbols used herein are defined
as follows:

C_L gross lift coefficient (L/qS)

$\Delta C_{L_{max}}$ increment of maximum lift coefficient

c_D drag coefficient corrected for jet-boundary interference (D/qS)

C_m gross pitching-moment coefficient $(M/qS\bar{c})$

c_{D_i} induced-drag coefficient $\left(C_L^2/\pi A\right)$

c_{D_p} parasite-drag coefficient $\left(c_D - c_{D_i}\right)$

Δc_{D_p} increment of parasite-drag coefficient

T_c thrust disk-loading coefficient for one propeller $\left(T_e/\rho V^2 D^2\right)$

$\sqrt{\overline{v^2}}$ root-mean-square value of the deviations, perpendicular to wind axis, of instantaneous local velocity from its mean value

U mean value of instantaneous local velocity along wind axis

q_t local dynamic pressure at tail

q free-stream dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$

α angle of attack of wing corrected for jet-boundary interference

δ_f wing-flap deflection measured from neutral flap position

R Reynolds number $(\rho V \bar{c}/\mu)$

where

L lift

D drag; propeller diameter

M pitching moment about center of gravity

T_e effective thrust of one propeller

S wing area (22.219 sq ft)

$\overline{c}$ mean aerodynamic chord (1.444 ft)

A   geometric aspect ratio $\left(\dfrac{b^2}{S} = 12.8\right)$

b   wing span (16.875 ft)

V   velocity in free stream

ρ mass density of air

μ coefficient of viscosity

MODEL

The general arrangement of the model is shown in figures 1 and 2. The model was of wood and metal construction and was finished with lacquer. Pertinent dimensions are given in table I.

The wing had Davis airfoil sections, 22.9 percent thick at the root and 9.3 percent thick at the tip. The maximum camber was approximately 3.4 percent of the chord at the root section and 1.4 percent at the tip. The location of the maximum camber was constant across the span at 31.5 percent of the local chord. The geometric aspect ratio of the wing was 12.8 and the taper ratio was 3.077:1.

The horizontal tail had no movable elevator. The vertical tail was off during all the tests.

The installation of the cowl flaps and intercooler exit flaps is shown in figure 3 for their deflected positions. The cowl flaps extended from the top of the cowling to a point slightly below the nacelle center line. The intercooler cooling-air exits were located on the upper surface of the wing.

STANDARD CONFIGURATION

The standard nacelle afterbodies (afterbody 1) are shown in figures 3 and 4 with wing flaps neutral. No part of the nacelle afterbody is on the upper surface of

the wing near the trailing edge. The extreme end of the
standard afterbodies was attached to the lower surface
of the wing flaps and deflected with the flaps, as shown
in figure 5. The wing flaps were of the Fowler type and
consisted of inboard and outboard sections. Ordinates
for the inboard section are given in table II. At the
inboard nacelle, the nose of the flap was 2.4 percent
wing chord ahead of and 2.9 percent wing chord below the
trailing edge of the wing.

MODIFICATIONS

In an attempt to delay separation of air flow on
the wing in the cruise condition, the original wing chord
was extended in order to reduce the peak pressures and
adverse pressure gradients. Leading-edge gloves (figs. 6
and 7) were built to NACA 64-series ordinates modified to
fair into the original Davis airfoil section. The gloves
extended the wing chord 10 percent between the fuselage
and the inboard nacelle and tapered to the original
leading edge at the outboard nacelle. Because these
gloves were added to the original wing, a perfect contour
could not be formed where the gloves faired into the wing.

The trailing-edge extension was a thin metal strip
attached to the flaps and deflected down 11° from the
lower surface of the flaps. The extensions were deflected
down 1° to 2° from the wing chord lines. The installation
of the extensions is shown in figure 7. Extensions of
two different spans and three different chords were tested.
Extensions attached only to the inboard flaps are desig-
nated 0.3 span, and extensions attached to both inboard
and outboard flaps are designated 0.6 span. The chords
were $1\frac{1}{2}$, $2\frac{1}{4}$, and 3 inches. Unless otherwise specified,
the term "trailing-edge extensions" designates the $1\frac{1}{2}$-inch-
chord extensions attached to both the inboard and outboard
flaps.

The installation of the various modified nacelle
afterbodies with wing flaps neutral is illustrated in
figures 8 to 10. Drawings of the modified nacelle after-
bodies are given in figures 11 to 13. Afterbodies 2
and 3, shown in figure 8, were attached to the inboard
nacelles only and differed mainly from the standard
afterbody in that they had a fairing on the upper surface

of the wing. Afterbody 4 (figs. 9 and 12) was a beaver-
tail afterbody with a small fairing on the upper surface
of the wing. Afterbody 5, shown in figures 10 and 13,
was faired on the upper surface of the wing forward to
the intercooler air exit. The lower part was extended
in order to obtain a better afterbody shape.

The installation of the deflected flaps with inboard
nacelle afterbodies 4 and 5 is shown in figures 14
and 15, respectively. With afterbodies 4, tests were
made with the flaps cut out below the afterbody as shown
in figure 14 and also with the flaps not cut and extending
below the afterbody. Inboard afterbodies 5 enveloped the
center part of the deflected flaps, and the flap-nacelle
juncture was faired with plasticine as shown in figure 15.
The tips of the modified afterbodies did not deflect with
the flaps.

A double slotted, or vaned, flap (fig. 16) was
tested in an attempt to improve the air flow over the
flap. The outside contour and the installation of the
flap and vane combination were the same as for the
original Fowler flap. The ordinates for the double
slotted flap are given in table II.

A P P A R A T U S   A N D   T E S T S

Tests of the model were made for two basic conditions:

(1) Cruise condition - wing flaps neutral,
     cowl and intercooler flaps closed

(2) Landing condition - wing flaps deflected 40°,
     landing gear down, cowl and intercooler
     flaps closed

For the cruise condition, a few tests were also made to
determine characteristics with cowl and intercooler flaps
open.

For the cruise condition, tests were made with the
model in the standard configuration and with leading-edge
gloves, trailing-edge extensions, and modified nacelle
afterbodies. For the landing condition, tests were made
with the model in the standard configuration and with
modified inboard afterbodies and modified inboard flaps.

The cowl flaps in the open position were deflected 10°. When the intercooler flaps were opened, the exit gap was increased 7/16 inch, which corresponds to the maximum deflection of the intercooler flaps. The air flow through the nacelle was adjusted, with the model at an angle of attack of 5°, to provide a pressure drop of approximately 0.75q through the cowling with cowl flaps open and a pressure drop of approximately 0.67q through the intercooler ducts with exit flaps closed.

For a flap deflection of 40°, the main landing gear was down; however, no provision was made for simulating open landing-gear doors. For flap deflections of 0° and 10°, the landing gear was removed. Most of the tests were made with the horizontal tail off. The vertical tail was off for all tests.

Power conditions were simulated by matching the thrust coefficients of the model and airplane at each lift coefficient. The variation of thrust coefficient with lift coefficient for sea-level power conditions is presented in figure 17. The thrust coefficients for 0.4 normal rated power at sea level correspond closely to those for cruising power (0.6 normal rated power) at 25,000 feet. The propeller blade angle at 0.75 radius was 30°.

It was believed that transition from laminar to turbulent flow on the airplane wing would occur at approximately the location of the front spar. In an attempt to make the results of the model tests more representative of flight conditions, most of the tests were made with the transition fixed at a chordwise station corresponding to the spar location. The transition was fixed by placing a strip of 60-grain carborundum on the upper and lower surfaces at the 10-percent-chord station of the original wing section. The width of the strip between the fuselage and the outboard nacelles was approximately 3/8 inch and tapered to approximately 1/4 inch at the tips.

The character of the flow over the wing and the nacelle afterbodies was determined by observing the behavior of tufts, which were attached to both the upper and lower surfaces of the wing and nacelle afterbodies. No tufts were placed ahead of the 20-percent-chord station of the wing. These tests were generally made with fixed transition and with propellers operating at 0.4 normal rated power; however, a few tests were made with natural transition and with propellers off.

Force and moment characteristics were measured by a six-component automatically recording balance system. Lift and drag were measured for all configurations. The effects of leading-edge gloves and trailing-edge extensions on the longitudinal stability characteristics were determined with the horizontal tail on (elevator neutral) for several power conditions.

Measurements of the air-stream turbulence were made at several spanwise stations along the elevator hinge line by means of a hot-wire anemometer. The basic principles of operation of this instrument are described in reference 1. The turbulence measurements were supplemented by measurements of the local dynamic pressures at the tail obtained from surveys with a rake of six pitot-static tubes. All surveys were made with fixed transition and with the propellers operating at 0.4 normal rated power.

All tests were made with the air in the tunnel compressed to an absolute pressure of approximately 35 pounds per square inch ($\rho \approx 0.00558$ slug/cu ft). Most of the tests were made at a Reynolds number of approximately 2.6×10^6 and a Mach number of 0.12; however, a few tests were made at a Reynolds number of 3.9×10^6 and a Mach number of 0.18.

RESULTS AND DISCUSSION

The results of the investigation are discussed from the standpoint of (1) flow over the wing and flap, (2) flow at the tail, (3) drag and lift, and (4) longitudinal stability. The characteristics of the standard model and the effect of the various modifications are shown for the cruise and landing conditions.

Jet-boundary corrections have been added to the angle of attack, drag coefficient, and the vertical position of the survey points with respect to the elevator hinge line as follows:

$$\Delta \alpha = 0.654 C_L$$

$$\Delta C_D = 0.0106 C_L^2$$

$$\Delta z = -0.13 C_L$$

where $\Delta\alpha$ is in degrees, Δz is in inches, and z is the vertical position of the survey points with respect to the elevator hinge line. No corrections have been applied to the data for the effects of model-support tare and interference or for air-stream misalinement.

FLOW CHARACTERISTICS AT THE WING

The results of tuft observations that show the character of the flow over the wing, flaps, and nacelles are given.

Cruise Condition

The stall progressions of the model in the original and modified configurations with wing flaps neutral are given in figures 18 to 22 for cowl and intercooler flaps closed. The values of lift coefficient at which separation first occurred on the wing are given in table III. Diagrams showing the flow over the wing at a lift coefficient of approximately 0.8 are presented in figure 23. Stall progressions for the model with cowl and intercooler flaps open are given in figure 24. The propellers were operating at 0.4 normal rated power and the transition was fixed at 10 percent wing chord except for two tests of the standard model. Diagrams are presented to show the effect of power and the effect of removing the transition strip on the wing.

Standard configuration.- With cowl and intercooler flaps closed, propellers operating at 0.4 normal rated power, and transition fixed, the initial stall on the wing occurred at a lift coefficient of about 0.63 with the model in the standard or original configuration (fig. 18(a)). The initial separation occurred on the rear part of the wing to the left of each nacelle. The flow over the wing directly behind each nacelle was rough but not separated for most angles of attack. With natural transition (fig. 18(b)) the stall patterns were about the same as with fixed transition but the initial separation occurred at a lift coefficient of about 0.91. With propellers off and transition fixed, the initial separation occurred at about the same lift coefficient as with the propellers operating, but at higher lift coefficients the area directly behind the inboard nacelles was stalled (fig. 18(c)).

Separated flow like that indicated in figure 18 produces an increase in drag and could cause buffeting. The purpose of the modifications was to delay this separation and to cause a general improvement in flow through the cruising range $(C_L = 0.6$ to $0.9)$. A substantial improvement in flow over the wing was obtained, as shown in figure 25(a), by deflecting the wing flaps 10°. The drag, however, was increased.

Chord extensions.- Chord extensions delayed the initial separation and improved the flow over the wing at higher lift coefficients.

Leading-edge gloves (fig. 19(a)) delayed the initial separation to a lift coefficient 0.12 higher than for the standard model. About the same improvement was realized with the $1\frac{1}{2}$-inch-chord 0.3-span trailing-edge extensions. The 0.6-span trailing-edge extensions were the most effective individual modification in improving the flow over the wing. The $1\frac{1}{2}$-inch-chord 0.6-span trailing-edge extensions (fig. 19(c)) delayed the initial separation to a lift coefficient 0.21 higher than for the standard model. More improvement resulted from the $2\frac{1}{4}$-inch-chord 0.6-span extensions. Subsequent tests, however, were made with the $1\frac{1}{2}$-inch-chord 0.6-span trailing-edge extensions because the greater improvement in flow with the $2\frac{1}{4}$-inch extensions did not seem sufficient to warrant the additional structural changes necessary to the airplane. In evaluating the improvement due to either leading-edge or trailing-edge extensions in terms of the increase in lift coefficient at which separation first occurred on the wing, it should be noted that the gain in lift coefficient was partly due to added wing area.

Modified nacelle afterbodies.- Modified nacelle afterbodies caused only a slight delay in the initial separation but improved the flow over the wing. This improvement is shown for afterbodies 2 and 3 by comparing figure 20 with figure 18(a) and for afterbodies 4 and 5 by comparing figures 21(a), 21(b), 22(a), and 22(b) with figures 19(a) and 19(c). Afterbodies 4 and 5 appear to be most effective. No flow separation occurred on the lower surface of either the standard or modified nacelles.

Combinations of chord extensions and modified nacelle
afterbodies.- Chord extensions, either leading edge or
trailing edge, in combination with modified nacelle
afterbodies were more effective in delaying separation
and in improving the flow over the wing than were chord
extensions or afterbodies alone. The combinations of
leading-edge gloves with afterbodies 4 and leading-edge
gloves with afterbodies 5 (figs. 21(a) and 22(a)) delayed
the initial separation to a lift coefficient approxi-
mately 0.16 higher than for the standard model. With
trailing-edge extensions in combination with either
afterbodies 4 or 5 (figs. 21(b) and 22(b)), the initial
separation occurred at a lift coefficient of about 0.91,
which is approximately 0.28 higher than for the standard
model. As shown in figure 21(c), a greater improvement
in flow was obtained with a combination of leading-edge
gloves, trailing-edge extensions, and afterbodies 4.
Separation on the inner wing sections was delayed to a
lift coefficient of over 1.0. A similar combination with
afterbodies 5 was only slightly more effective than the
combination of trailing-edge extensions with afterbodies 5.

Cowl and intercooler flaps open.- With the model in
the standard configuration, opening the cowl and inter-
cooler flaps caused separation of the flow over the wing
directly behind them at all lift coefficients (fig. 24(a)).
The addition of trailing-edge extensions reduced the
extent of the stalled area, as shown in figure 24(b).
With afterbodies 4 and trailing-edge extensions on the
model (fig. 24(c)), the initial separation behind the open
intercooler flaps was delayed until a lift coefficient of
about 0.55 had been reached. With inboard afterbodies 5
and trailing-edge extensions on the model, no separation
occurred behind the open intercooler flaps of the inboard
nacelles (fig. 24(d)).

Landing Condition

Stall characteristics of the standard and modified
model with wing flaps deflected are shown in figures 25
to 27. For these configurations the propellers were
operating at 0.4 normal rated power, the transition was
fixed, and the cowl and intercooler flaps were closed.

Standard configuration.- With the standard configu-
ration and flaps deflected 40° (fig. 25(b)), the initial
stall on the wing occurred ahead of the ailerons and was

followed by separation between the nacelles. For all
angles of attack and all flap deflections, separation
occurred on the part of the flaps blanketed by the
nacelles. The flow over the lower surface of the nacelle
and the part of the afterbody that deflected with the
flap was not separated. (See fig. 26(a).) Removing the
afterbody tips from the standard model did not improve
the flow over the flaps. It was thought that separated
flow over the inboard flaps combined with irregular flow
created by the afterbody tips would probably contribute
most to any tail buffeting. Modifications for the landing
condition were therefore directed toward improving the
air flow at the inboard nacelles.

    Modifications.- With double slotted inboard flaps
deflected 40° (fig. 26(b)), the flow over the right flap
was not separated but the left flap was stalled, as was
the standard flap. From tests made with the afterbody
tips removed and with power off, the separation over the
double slotted inboard flaps at 0.4 normal rated power
appeared to be caused by the afterbody tip, which
deflected with the flap, and the dissymmetry appeared to
be associated with the rotation of the slipstream. When
the standard flaps were continuous and were deflected
through afterbodies 4 (fig. 26(c)), the lower part of
the afterbody and the surface of the flap below the
afterbody were stalled at all angles of attack. With
the flaps cut out at inboard afterbodies 4, as shown in
figure 14, no stall occurred on the flap or nacelle
(fig. 26(d)). The same flow existed with trailing-edge
extensions on the flaps. With the standard flaps
deflected within afterbodies 5 (fig. 26(e)), the flow
over the flaps and afterbodies was not separated at any
angle of attack. Adding trailing-edge extensions had
little effect on the flow if the extensions were cut out
below the nacelles (fig. 26(f)).

    The most promising methods of those investigated
for improving the flow over the flap were enclosing the
flap rear of the inboard nacelle within afterbody 5 or
cutting the flap at the nacelle. Trailing-edge exten-
sions and modified afterbodies, to a lesser extent,
delayed separation on the inner wing panels and thus
aggravated the tendency toward early tip stalling indi-
cated by stall studies of the standard model. This
effect could be minimized by reducing the wing-flap
deflection.

FLOW CHARACTERISTICS AT THE TAIL

The results of turbulence surveys at the tail are presented in figures 28 to 31 for the standard model and for several modifications. Diagrams showing the flow characteristics over the wing for conditions at which surveys were made are given in figure 32. The turbulence data are presented as the variation of root-mean-square value of the vertical velocity deviations with vertical distance for several spanwise stations. Axial velocity deviations were of the same order of magnitude as vertical velocity deviations. Maximum values of the velocity deviation are several times the root-mean-square values. The vertical velocity deviations may be interpreted as angle-of-attack changes; for example, a value

of $\sqrt{\overline{v^2}}/U$ of 0.04 is equivalent to a root-mean-square angle deviation of slightly over 2°.

Buffeting tendencies are difficult to evaluate quantitatively because the root-mean-square deviation indicates neither the large fluctuations that may occur nor the frequency. Both of these factors play an important role in determining buffeting characteristics. The main value of the data presented is the indication of the effects of the modifications on the turbulent wake. The curves indicate the normal wake of the wing and nacelles by an increase of turbulence. Beyond this main turbulent wake, there are small peaks that define the edge of the slipstream.

The variations of local dynamic pressure with vertical distance for the standard model are indicated in figures 33 to 35. The curves show increases in dynamic pressure due to the slipstream and depressions due to wing or nacelle wake. The point at which the maximum depression occurs has been assumed to be the center of the wake. The variations of wake-center position with lift coefficient are given in figures 36 and 37 for the standard and modified models. Except for displacement, the modifications changed the profile of the dynamic-pressure wake very little.

The vertical position of the peak values of turbulence agree closely with the position of the dynamic-pressure wake centers. The vertical extent of the main turbulent wake is roughly the same as that for the

dynamic-pressure wake. A comparison of the turbulence
and dynamic-pressure-survey data indicates that only a
slight amount of turbulence is produced by the slipstream;
the greater part of the turbulence is produced by the
wake of the wing and nacelles.

Cruise Condition

Standard configuration.- For the standard model with
cowl and intercooler flaps closed (fig. 28), the largest
turbulent wake and the maximum turbulence occurred at
stations 13 inches right and 27 inches left of the fuse-
lage center line, which are behind stalled parts of the
wing (fig. 32). The maximum value of $\sqrt{\overline{v^2}}/U$ obtained
with cowl and intercooler flaps closed was 0.04. As shown
in figures 28 and 33, the variations of turbulence and
dynamic pressure are different on the left and right
sides of the fuselage center line. The growth of turbu-
lence on the left side from the high-speed condition
through the cruise condition is illustrated in figure 29.
At stations to the right and left of the inboard nacelle
(13 in. and 27 in. from fuselage center line) the turbu-
lence increased with increasing angle of attack. Directly
behind the nacelle, the turbulence decreased slightly as
the angle of attack increased from 4.4° to 7.6°. With
increasing angle of attack, the wake centers moved up in
relation to the elevator hinge line (figs. 29 and 36).

Combinations of chord extensions and modified nacelle
afterbodies.- The effects of modifications, in general,
were to reduce the extent and magnitude of the turbulence
and to displace the whole turbulent wake downward. As
shown in figure 28, the greatest reduction in turbulence
was obtained with afterbodies 4 in combination with
trailing-edge extensions. The combination of after-
bodies 5, trailing-edge extensions, and leading-edge
gloves was somewhat less effective; and the combination
of afterbodies 5 and trailing-edge extensions was the
least effective in reducing turbulence. The greatest
reductions in turbulence were obtained at stations
13 inches right and 27 inches left and right of the fuse-
lage center line. These reductions are apparently due
to modifications delaying separation on the wing at these
stations. At the station directly behind the nacelles
(20 in.), afterbodies 4 caused a definite reduction in

turbulence whereas afterbodies 5 caused little change.
The downward displacement of the wake due to modifica-
tions would be greater than shown in figure 28 if the
data were compared at the same lift coefficient. (See
fig. 36.)

     Cowl and intercooler flaps open.- Comparison of
figures 28 and 30 shows that opening the cowl and inter-
cooler flaps caused large increases in the turbulence at
the tail both with the standard model and with after-
bodies 5 and trailing-edge extensions. The magnitude
and extent of the velocity fluctuations were, however,
much lower for the model with afterbodies 5 and trailing-
edge extensions.

                        Landing Condition

     The results of surveys for the landing condition are
given in figure 31 for a spanwise station behind the
inboard nacelle. With both the standard and modified

models, the maximum value of $\sqrt{\overline{v^2}}/U$ occurred below the
elevator hinge line.

     With the flaps deflected within afterbodies 5, the
turbulence was less than for the standard model. With
flaps continuous and deflected through afterbodies 4,
slightly greater turbulence was obtained than for the
standard model. The increased turbulence was evidently
due to the stall that occurred on the flap and lower
part of the afterbody (fig. 26(c)). With the flaps cut
out below the nacelle as shown in figure 14, the turbu-
lence would probably be less than for the standard model.

                  DRAG AND LIFT CHARACTERISTICS

     The variations of the parasite-drag coefficient with
lift coefficient for the standard and modified model are
shown in figures 38 to 45. The lift, drag, and pitching-
moment characteristics for the cruise and landing condi-
tions are given in figures 46 to 52. Table III gives the
numerical values of the drag changes due to modifications
at several lift coefficients and the increments of
maximum lift coefficients due to the modifications

obtained in the cruising condition. The data have not
been corrected for support tares or air-stream misaline-
ment and therefore should not be considered as absolute
values nor should the shape of the curves be considered
correct. It is believed, however, that the changes in
drag and lift due to modifications would not be materially
affected by the application of such corrections.

Cruise Condition

Inasmuch as flight Reynolds numbers are much greater
than that at which the tests were conducted, the inter-
pretation of the drag reductions due to the modifications
is difficult, particularly in the range where separation
occurs. The value of drag reductions obtained at a given
lift coefficient of the model may not be in agreement
with reductions that would be obtained from tests of the
full-scale airplane. The results of the model tests,
however, are believed to be indicative of the results
that would be obtained from installation of the modifi-
cations on the airplane.

Figure 38 presents the data obtained from runs made
near the beginning, middle, and end of the investigation
with fixed and natural transition. The displacement of
the test points gives an indication of how closely test
conditions (primarily model surface condition) could be
duplicated. Fixing the transition at 10 percent wing
chord increased the drag coefficient at all values of
lift coefficient and also decreased the lift coefficient
at which the rapid increase in drag occurs.

The effect of Reynolds number on drag characteris-
tics with transition fixed is shown in figure 39. The
drag for each model configuration was lower at all lifts
at a Reynolds number of 3.9×10^6 than at a Reynolds
number of 2.6×10^6, and the knee in the drag curves
occurred at higher lifts with the higher Reynolds number.

Chord extensions.- The effect of span and chord of
the trailing-edge extensions in reducing drag is shown

in figure 40. At a lift coefficient of 0.7, reductions with 0.3-span and 0.6-span extensions were approximately in the ratio of 3:4. The $2\frac{1}{4}$-inch-chord extensions reduced the drag somewhat more than the $1\frac{1}{2}$-inch extensions. No further reduction was realized by increasing the chord to 3 inches. Subsequent tests were made with the 0.6-span $1\frac{1}{2}$-inch-chord trailing-edge extensions.

Changes in drag caused by trailing-edge extensions and leading-edge gloves were dependent upon the type of transition. The $1\frac{1}{2}$-inch-chord 0.6-span trailing-edge extensions reduced the drag coefficient of the model by 0.0038 with transition fixed at a lift coefficient of 0.7 (fig. 41(a)). With natural transition (fig. 41(b)), the trailing-edge extensions increased the drag 0.0003 at a lift coefficient of 0.7 but at lift coefficients above 0.8 appreciable reductions were obtained. Leading-edge gloves reduced the drag coefficient by 0.0028 at a lift coefficient of 0.7 with fixed transition and by 0.0012 with natural transition (fig. 41). Because of the imperfect contour formed where the gloves faired into the wing, the results obtained with the wing modified in this manner are probably not so good as would be obtained if the wing were built to the revised dimensions.

Modified nacelle afterbodies.- All modified inboard nacelle afterbodies reduced the drag of the model at cruising lifts (fig. 42) but had little effect at low lifts. The order of increasing effectiveness was afterbodies 2, 3, 4, and 5. Modified afterbodies on all four nacelles reduced the drag at all lift coefficients. Four afterbodies 4 reduced the drag coefficient of the model by 0.0034 with fixed transition and 0.0017 with natural transition at a lift coefficient of 0.7 (fig. 43). Four afterbodies 5 (fig. 44) were somewhat less effective in reducing the drag than four afterbodies 4. Modified nacelle afterbodies were the most effective individual modifications in reducing drag when considering both fixed and natural transition on the wing; however, trailing-edge extensions were slightly more effective with fixed transition.

Propellers-off stall studies of the standard model (fig. 18(c)) show that at a lift coefficient of about 0.7

the flow behind the inboard nacelles was separated but
the flow behind the outboard nacelles was smooth. These
studies and a consideration of the shape of the drag
curves indicate that the modified inboard afterbodies
reduce the drag by delaying separation on the wing,
whereas the modified outboard afterbodies reduce the drag
by improving the afterbody form. This explanation
probably accounts for the differences between the effec-
tiveness of the inboard and outboard afterbody
modifications.

Combinations of chord extensions and modified nacelle
afterbodies.- The combination of chord extensions and
modified nacelle afterbodies generally was more effective
in reducing drag than either modification alone. Some of
the more effective combinations with the drag-coefficient
reductions at $C_L = 0.7$ are as follows:

Modification	Fixed transition	Natural transition
Four afterbodies 4 and trailing-edge extensions	0.0045	0.0015
Four afterbodies 5 and trailing-edge extensions	0.0038	0.0005
Four afterbodies 5 and leading-edge gloves	0.0046	0.0015
Four afterbodies 5, leading-edge gloves, and trailing-edge extensions	0.0048	0.0017

There appears to be no advantage in combining leading-
edge gloves with afterbodies 4 for reducing drag.

All modifications increased the maximum lift coeffi-
cient of the model with either fixed or natural transi-
tion, and most of the modifications increased the slope
of the lift curve.

Cowl and intercooler flaps open.- With the model in
the standard configuration, opening the cowl and

intercooler flaps caused a large increase in drag. (Compare figs. 45 and 38.) The resulting high drag coefficient was decreased 0.0072 at a lift coefficient of 0.7 by the addition of inboard afterbodies 5 and trailing-edge extensions or four afterbodies 4 and trailing-edge extensions (fig. 45). It should be noted that these modifications reduced the drag coefficient approximately 0.0040 with cowl and intercooler flaps closed.

Landing Condition

The lift characteristics for the standard and modified models with wing flaps deflected 40° are presented in figure 52. With transition fixed and propellers off, the same maximum lift coefficient was obtained with double slotted inboard flaps or with standard flaps deflected within afterbodies 5 as was obtained with the model in the standard configuration.

In order to eliminate flow separation that occurred on the flaps and the rear part of afterbodies 4, part of the inboard flaps were cut away. This change resulted in a reduction of about 0.1 in the maximum lift coefficient. An additional reduction would result if the outboard flaps were cut. With flaps deflected through either afterbodies 4 or 5, the addition of trailing-edge extensions increased the maximum lift coefficient by about 0.2; the resulting lift coefficient was greater in both cases than for the standard model.

LONGITUDINAL STABILITY CHARACTERISTICS

Pitching-moment curves for the standard and modified model with propellers removed and horizontal tail off are presented in figures 46 to 51. Power-on pitching-moment curves with horizontal tail on and off are presented in figures 53 to 55. No corrections have been applied to the pitching moments but the results presented indicate the effect of the various modifications. With tail on, the large differences in trim and the fact that large parts of the curves are considerably out of trim make an accurate evaluation of stability changes difficult. Moment curves for several elevator or stabilizer settings would be required.

As indicated by changes in the slopes of the pitching-
moment curves, leading-edge gloves and trailing-edge
extensions caused appreciable reductions in longitudinal
stability.

Cruise Condition

With wing flaps neutral and the horizontal tail on
(fig. 53), the pitching-moment curves show that the model
with chord extensions and modified afterbodies was less
stable than the standard model for all power conditions.
Up to a lift coefficient of 0.6, the combination of
trailing-edge extensions and inboard afterbodies 5 changed
the moment-curve slope dC_m/dC_L approximately 0.04
to 0.06 from the standard configuration. The combination
of leading-edge gloves, trailing-edge extensions, and
afterbodies 5 changed the slope approximately 0.08 to 0.10
from the standard configuration. Above a lift coefficient
of 0.6, the modifications were more destabilizing,
probably because the delayed separation on the inner wing
panel results in increased downwash. A satisfactory
compromise between the adverse stability changes and flow
and drag improvements due to trailing-edge extensions
could probably be obtained with an extension having a
smaller chord than those tested.

Landing Condition

With wing flaps deflected, horizontal tail on, and
propellers operating at 0.4 normal rated power (fig. 54(b)),
the slope of the pitching-moment curve was approxi-
mately 0.04 less negative (model less stable) with the
combination of trailing-edge extensions and afterbodies 5
on the model. With leading-edge gloves, trailing-edge
extensions, and afterbodies 5 on the model, the slope of
the moment curve was 0.07 less negative than with the
model in the standard configuration. With propellers
operating at zero thrust (fig. 54(a)), only a slight
change in the slope of the moment curve was caused by
either modification. The adverse effects on stability
could be minimized by reducing the flap deflection.

CONCLUSIONS

From an investigation of a model of a four-engine bomber-type airplane that was made to determine effects of wing and nacelle modifications on drag and air flow at the tail, the following results were shown:

1. Worth-while improvements in the characteristics of the model were obtained with certain modifications. The improvements were indicated on the basis of improved flow over the wing and deflected flaps, reduced turbulence in the region of the tail, and reduced drag.

2. Trailing-edge extensions were the most effective individual modification in improving the flow over the wing with wing flaps neutral, cowl and intercooler flaps closed. Modified nacelle afterbodies were the most effective individual modification in reducing drag with either fixed or natural transition on the wing; however, trailing-edge extensions were slightly more effective with fixed transition. Four afterbodies 4 (a beaver-tail type) alone were superior to four afterbodies 5 (an extended conventional afterbody) alone in reducing drag. Combinations of either leading- or trailing-edge extensions and modified afterbodies were more effective in delaying separation and reducing the drag than either modification alone.

3. With the model in the standard configuration, opening the cowl and intercooler exit flaps caused separation on the wing behind the intercooler air exit, increased the drag considerably, and increased the turbulence at the tail. These conditions were greatly improved by adding modified nacelle afterbodies and trailing-edge extensions.

4. With wing flaps deflected, enclosing the flap behind the inboard nacelle within nacelle afterbody 5 or cutting the flaps at the nacelle appear to be the most promising methods of improving the flow over the flaps and reducing the turbulence at the tail.

5. Although the results of turbulence surveys made with a hot-wire anemometer do not indicate definitely that buffeting would occur with the standard model or that the modifications would eliminate buffeting, the modifications did reduce the turbulence at the tail with wing flaps either neutral or deflected.

6. Appreciable reductions in the longitudinal sta-
bility of the model were caused by leading-edge gloves
and trailing-edge extensions. In the landing condition,
chord extensions also aggravated the tendency toward
early tip stalling obtained with the standard model.

7. All modifications increased the maximum lift with
wing flaps neutral and gave a maximum lift equal to or
greater than that for the standard model with wing flaps
deflected except when the inboard flaps were cut out
below afterbodies 4.

Langley Memorial Aeronautical Laboratory
      National Advisory Committee for Aeronautics
            Langley Field, Va.

R E F E R E N C E

1. Dryden, H. L., and Kuethe, A. M.: The Measurement
      of Fluctuations of Air Speed by the Hot-Wire
      Anemometer. NACA Rep. No. 320, 1929.

TABLE I
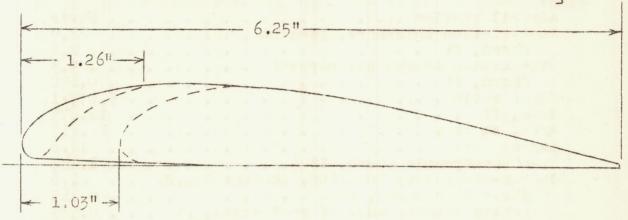
GENERAL SPECIFICATIONS OF MODEL

Wing:
    Airfoil section . . . . Davis
    Root-section thickness, percent 22.9
        Chord, ft 2.0
    Tip-section thickness, percent 9.3
        Chord, ft 0.650
    Taper ratio 3.077:1
    Span, ft 16.875
    Area, sq ft 22.219
    Aspect ratio 12.8
    Mean aerodynamic chord, ft 1.444
    Center-of-gravity location, percent M.A.C. . . 21.6
        Above root chord, ft 0.183
        Behind leading edge of root chord, ft . . . 0.525
    Incidence (with respect to fuselage
       center line), deg 3.0
    Geometric twist, deg 0

Fuselage:
    Over-all length, ft 10.386
    Maximum diameter, ft 1.187
    Maximum frontal area, sq ft 1.107

Nacelles:
    Frontal area (each), sq ft 0.450
    Incidence (with respect to wing chord), deg . . -3.0

Horizontal tail:
    Area, sq ft 5.201
    Span, ft 5.375
    Incidence (with respect to fuselage
       center line), deg . . . . -1.0
    Elevator hinge-line location (fuselage
      horizontal)
      Horizontal distance rear of leading edge of
        root chord, ft 5.866
      Vertical distance below leading edge of
        root chord, ft 0.031

Propellers:
    Number 4
    Diameter, ft 2.082
    Blades 4
    Blade design . . . . Curtiss Wright 1016-16

TABLE II

ORDINATES FOR FOWLER AND DOUBLE SLOTTED FLAPS

[Stations and ordinates given in inches and are measured from leading edge and reference line of Fowler flap]

Fowler flap		
Station	Upper surface	Lower surface
0	0.196	0.196
.078	.364	.078
.156	.442	.062
.312	.554	.048
.469	.632	.044
.625	.688	.040
.937	.769	.034
1.250	.819	.026
1.875	.844	.014
2.500	.821	.006
3.125	.760	0
3.750	.653	0
4.375	.522	0
5.000	.366	0
5.625	.220	0
6.25	.040	0
L.E. radius: 0.125		

Double slotted flap		
Vane		
Station		Lower surface
0.156		0.06
.28		.12
.41		.30
.53		.46
.78		.64
1.03		.75
1.26		.82
Nose of flap		
Station	Upper surface	Lower surface
1.03	0.20	0.20
1.11	.38	.05
1.19	.45	.03
1.34	.56	-------
1.50	.64	-------
1.66	.70	-------
1.97	.78	-------
2.28	.82	-------
2.50	.82	-------

TABLE III

EFFECT OF MODIFICATIONS ON DRAG, STALL, AND LIFT IN THE CRUISE CONDITION

$[\delta_f = 0°;$ cowl and intercooler flaps closed; $R \approx 2,600,000]$

Modifications	ΔC_{D_p} with fixed transition		ΔC_{D_p} with natural transition		C_L at first stall, 0.4 normal rated power, fixed transition	$\Delta C_{L_{max}}$ with propellers off	
	$C_L = 0.4$	$C_L = 0.7$	$C_L = 0.7$	$C_L = 0.9$	(a)	Fixed transition	Natural transition (b)
None	--------	--------	--------	--------	0.63	--------	--------
[c]Two afterbodies 2	0	-0.0005	--------	--------	0.64	--------	--------
[c]Two afterbodies 3	0	-0.0010	--------	--------	0.65	--------	--------
[c]Two afterbodies 4	0	-0.0015	--------	--------	--------	--------	--------
[c]Two afterbodies 5	0	-0.0021	--------	--------	--------	--------	--------
Four afterbodies 4	-0.0008	-0.0034	-0.0017	-0.0029	--------	0.09	0.11
Four afterbodies 5	-0.0006	-0.0027	-0.0011	-0.0021	--------	0.07	0.10
L.E. gloves	-0.0003	-0.0028	-0.0012	0.0019	0.75	0.05	--------
L.E. gloves, four afterbodies 4	-0.0006	-0.0042	-0.0004	0	[d]0.80	0.15	--------
L.E. gloves, four afterbodies 5	-0.0010	-0.0046	-0.0015	-0.0016	[d]0.79	0.15	--------
T.E. extensions	-0.0003	-0.0038	0.0003	-0.0010	0.84	0.12	0.14
T.E. extensions, four afterbodies 4	-0.0008	-0.0045	-0.0015	-0.0029	0.91	0.17	0.20
T.E. extensions, four afterbodies 5	-0.0002	-0.0038	-0.0005	-0.0017	[d]0.91	0.19	0.25
L.E. gloves, T.E. extensions	--------	--------	-0.0004	0	--------	--------	--------
L.E. gloves, four afterbodies 4, T.E. extensions	-0.0009	-0.0051	-0.0007	-0.0011	[d]1.04	0.24	--------
L.E. gloves, four afterbodies 5, T.E. extensions	-0.0006	-0.0048	-0.0017	-0.0025	[d]0.90	0.28	--------

[a]Lift coefficient given is that at which separation of flow first occurred on wing.
[b]For configurations with L.E. gloves, see lift curves.
[c]When two modified nacelle afterbodies were tested, they were fitted to inboard nacelles only.
[d]Stall studies with modified inboard afterbodies only.

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Figure	Material presented
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2	Model mounted in test section
3	Photograph, standard nacelle afterbodies, $\delta_f = 0°$
4	Drawing, standard nacelle afterbodies
5	Photograph, standard nacelle afterbodies, $\delta_f = 40°$
6	Drawing, L.E. gloves
7	Photograph, L.E. gloves and T.E. extensions
8	Photograph, nacelle afterbodies 2 and 3
9	Photograph, nacelle afterbodies 4, $\delta_f = 0°$
10	Photograph, nacelle afterbodies 5, $\delta_f = 0°$
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16	Photograph, double slotted flap
17	Calculated thrust coefficients for B-32 airplane

b. Stalling Characteristics; 0.4 Normal Rated Power; Transition Fixed

Figure	Configuration	δ_f (deg)	Cowl and inter- cooler flaps
18(a)	Standard model	0	Closed
[a]18(b)	------do-------------------------------	0	Do.
[b]18(c)	------do-------------------------------	0	Do.
19	Chord extensions	0	Do.
20	Modified inboard afterbodies	0	Do.
21	Inboard afterbodies 4 and chord extensions	0	Do.
22	Inboard afterbodies 5 and chord extensions	0	Do.
23	Comparison of stall patterns at $C_L \approx 0.8$	0	Do.
24	Standard and modified model	0	Open
25(a)	Standard model	10	Closed
25(b)	------do-------------------------------	40	Do.
26	Standard and modified model (flow over inboard afterbodies and flaps)	40	Do.
27	Modified model (flow over wing)	40	Do.

[a]Natural transition.
[b]Propellers off.

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INDEX TO FIGURES - Concluded

c. Tail-Survey Data; 0.4 Normal Rated Power; Transition Fixed

Figure	Material presented	Form of data	δ_f (deg)	Cowl and inter-cooler flaps
28	Standard and modified model, $\alpha = 7.6°$ and $8.7°$	$\frac{\sqrt{2}}{U}$ against vertical distance	0	Closed
29	Effect of angle of attack		0	Do.
30	Standard and modified model, $\alpha = 7.5°$		0	Open
31	Standard and modified model, $\alpha = 12.7°$		40	Closed
32	Stall patterns for survey conditions	----	----	----
33	Standard model	$\frac{q_t}{q}$ against vertical distance	0	Closed
34	-----do-----		0	Open
35	-----do-----		40	Closed
36	Position of wake center	Vertical distance against C_L	0	Do.
37	-----do-----		0	Open

d. Aerodynamic Characteristics with Propellers Off

Figure	Material presented	Form of data	δ_f (deg)	Cowl and inter-cooler flaps	Transition
38	Several runs with standard model	C_{D_p} against C_L	0	Closed	Fixed and natural
39	Effect of Reynolds number	-----do-----	0	-----do-----	Fixed
40	T.E. extensions	-----do-----	0	-----do-----	Do.
41	Standard afterbodies with chord extensions	-----do-----	0	-----do-----	Fixed and natural
42	Effect of various nacelle afterbodies	-----do-----	0	-----do-----	Fixed
43	Afterbodies 4 with chord extensions	-----do-----	0	-----do-----	Fixed and natural
44	Afterbodies 5 with chord extensions	-----do-----	0	-----do-----	Do.
45	Effect of modifications with cowl and intercooler flaps open	-----do-----	0	Open	Fixed
46	Effect of transition	C_D, α, C_m against C_L	0	Closed	Fixed and natural
47	T.E. extensions	-----do-----	0	-----do-----	Fixed
48	Standard afterbodies with chord extensions	-----do-----	0	-----do-----	Fixed and natural
49	Afterbodies 4 with chord extensions	-----do-----	0	-----do-----	Do.
50	Afterbodies 5 with chord extensions	-----do-----	0	-----do-----	Do.
51	Effect of modifications with cowl and intercooler flaps open	-----do-----	0	Open	Fixed
52	Effect of modifications on lift	C_L against α	40	Closed	Do.

e. Longitudinal Stability Characteristics; Transition Fixed

Figure	Configuration	δ_f (deg)	Cowl and inter-cooler flaps	Tail	Power
53(a)	Standard and modified model	0	Closed	On	$T_c = 0$
53(b)	------------do------------	0	------do-------	-do-	0.4 normal rated power
53(c)	------------do------------	0	------do-------	-do-	Normal rated power
54(a)	Standard and modified model	40	------do-------	On	$T_c = 0$
54(b)	------------do------------	40	------do-------	-do-	0.4 normal rated power
55(a)	Standard and modified model	0	------do-------	Off	0.4 normal rated power
55(b)	------------do------------	40	------do-------	-do-	0.4 normal rated power

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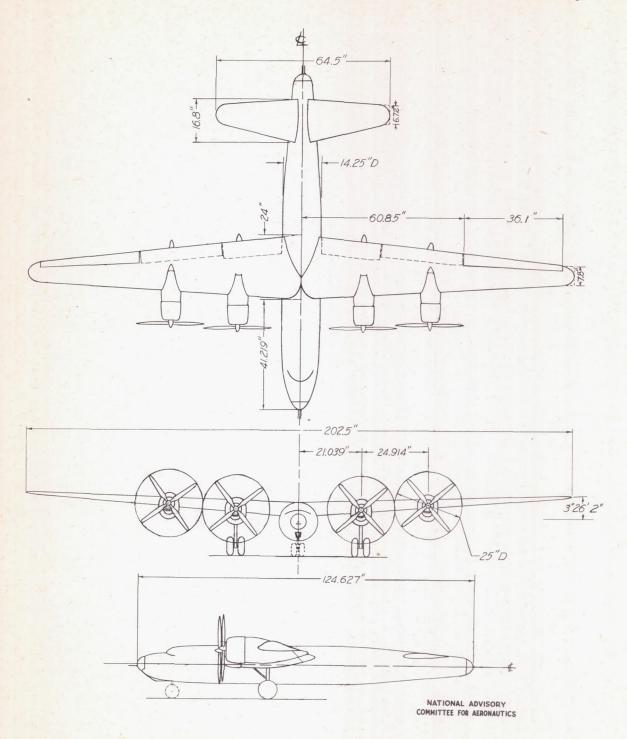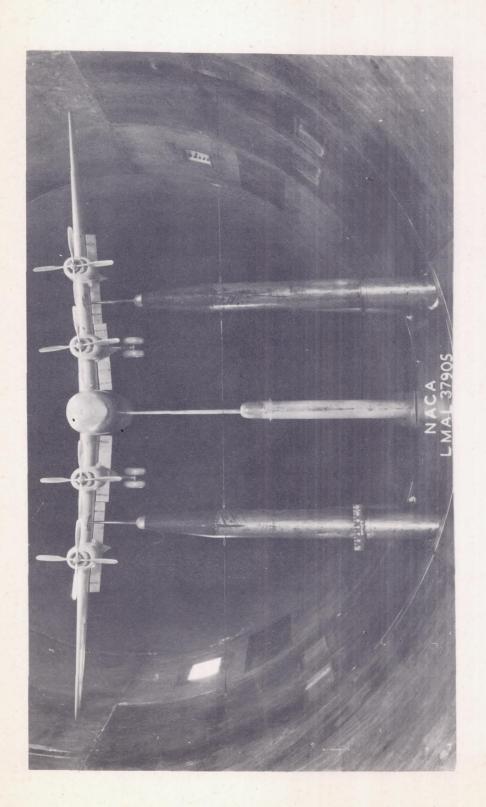
Figure 1.— Three-view drawing of model.

Figure 2.- Model mounted in test section of Langley 19-foot pressure tunnel.
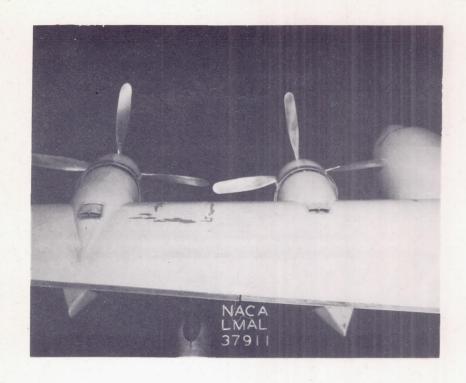
Figure 3.- Standard nacelles. $\delta_f = 0°$.

STATION
(PERCENT
CHORD)

0   18.1   78.3   100   111 114

WING
LEADING
EDGE

WING
TRAILING
EDGE

0   18.1   78.3   100   111 114

0 1 2 3 4 5
SCALE, IN.

INTERCOOLER
FLAP

CHORD
LINE

THRUST
LINE

3°

18.1

111
100
78.3

18.1

JOINT

3.73"   9.22"   16.14"   20.63" 22.97" 23.61"

0   18.1   78.3   100   111 114

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SECTIONS

(a) Inboard.
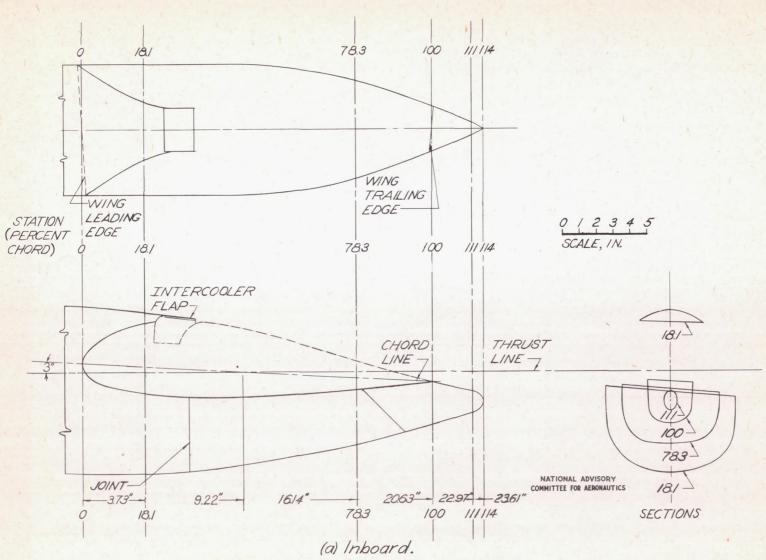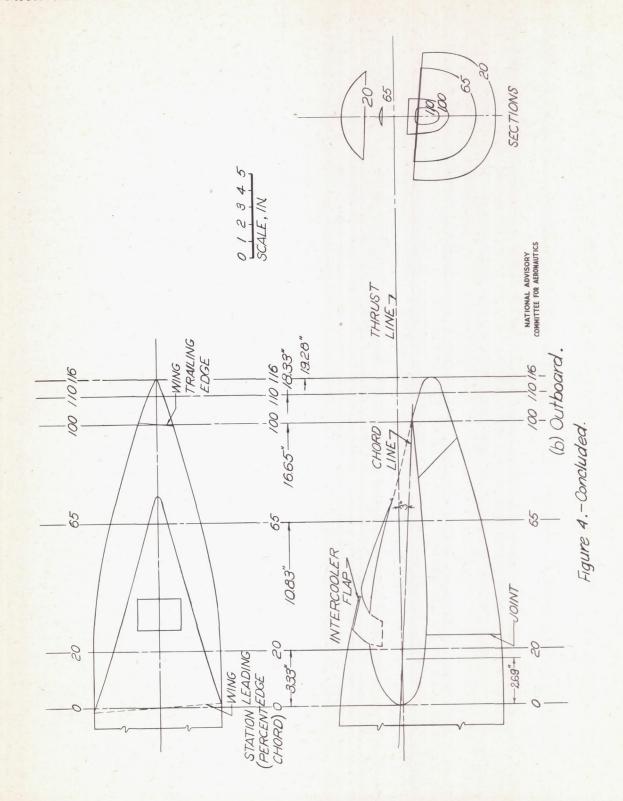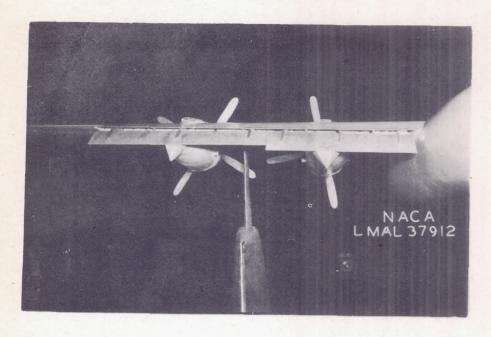
Figure 4.— Standard nacelle afterbody.

Figure 4.- Concluded.

(b) Outboard.
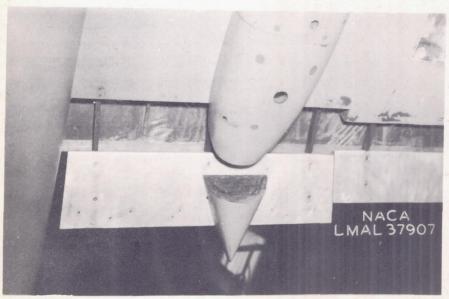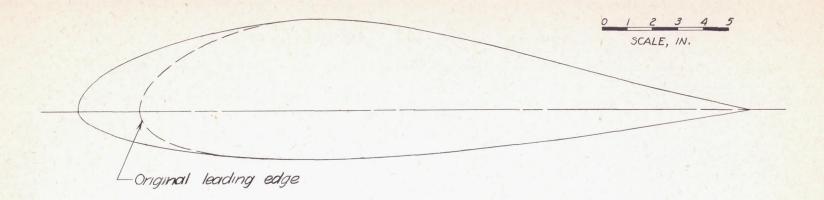
Figure 5.- Standard nacelles. $\delta_f = 40°$.

0 1 2 3 4 5
SCALE, IN.

Original leading edge

SCALE, IN.
0 5 10 15 20 25

Ordinates of Wing Section with Leading-Edge Gloves
at Model Center Line

[Station ordinates in percent of wing chord]

Station	Upper surface	Lower surface	Station	Upper surface	Lower surface
0	0	0	40	13.395	7.184
.5	2.436	.982	45	12.891	6.973
.75	2.764	1.264	50	12.079	6.675
1.25	3.309	1.750	55	11.068	6.282
2.50	4.445	2.527	60	9.891	5.791
5.00	6.141	3.618	65	8.632	5.232
7.50	7.423	4.368	70	7.314	4.627
10	8.500	4.982	75	6.000	3.959
15	10.223	5.907	80	4.673	3.277
20	11.514	6.547	85	3.386	2.518
25	12.468	7.009	90	2.159	1.730
30	13.135	7.245	95	1.032	.877
35	13.491	7.332	100	.059	.059

L.E. radius: 2.836
Slope of L.E. radius: 0.2527

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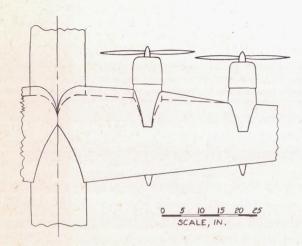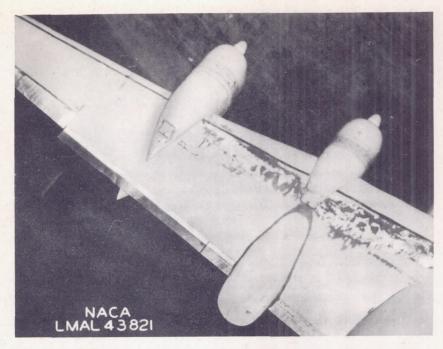
Figure 6.- Details of leading-edge glove.

Fig. 6

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LMAL 43821
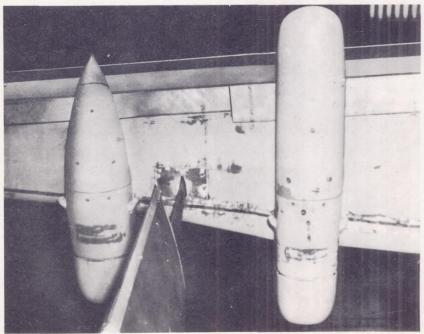
Figure 7.- Leading-edge gloves and trailing-
edge extensions.

(a) Afterbody 2.

(b) Afterbody 3.

Figure 8.- Inboard nacelle afterbodies 2 and 3.
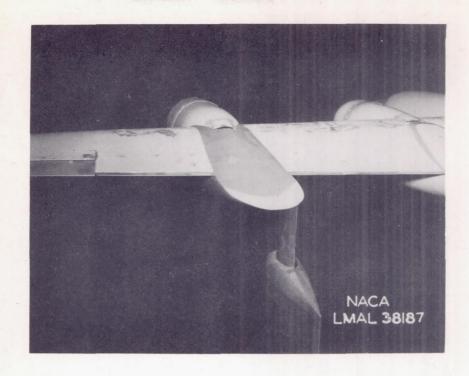
Figure 9.- Nacelle afterbody 4. $\delta_f = 0°$.
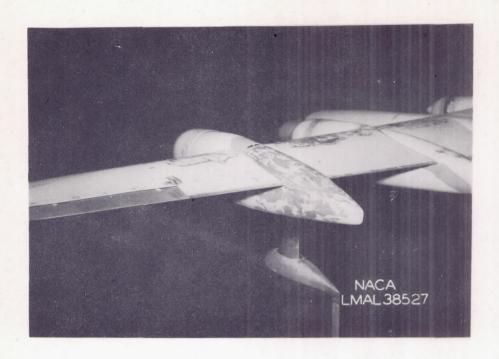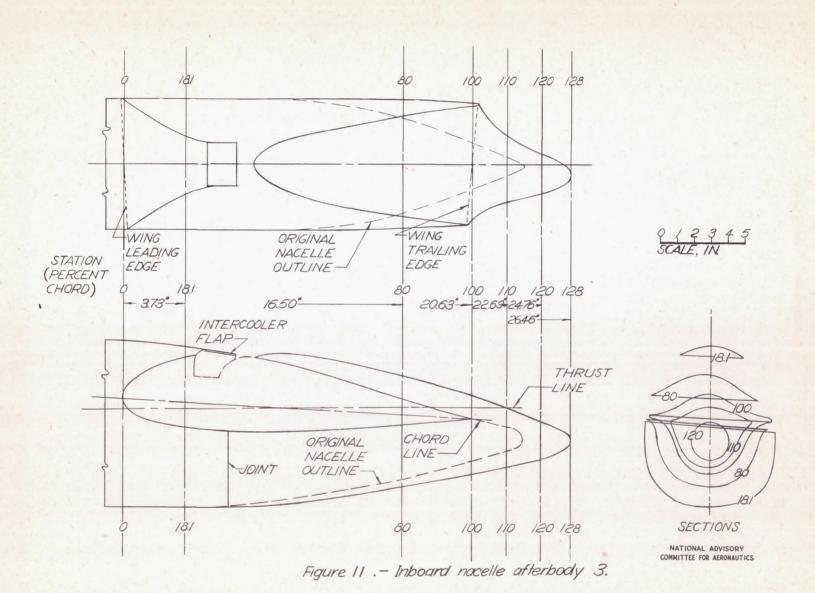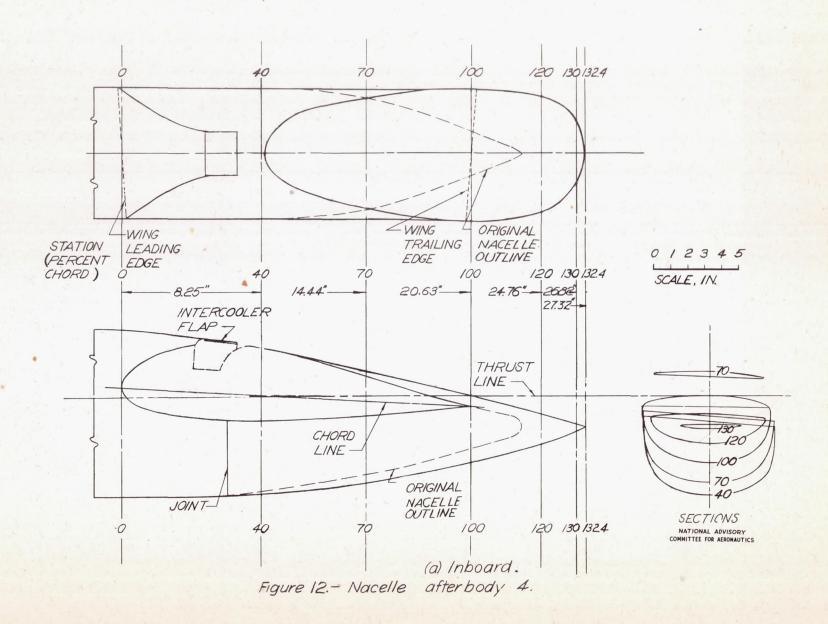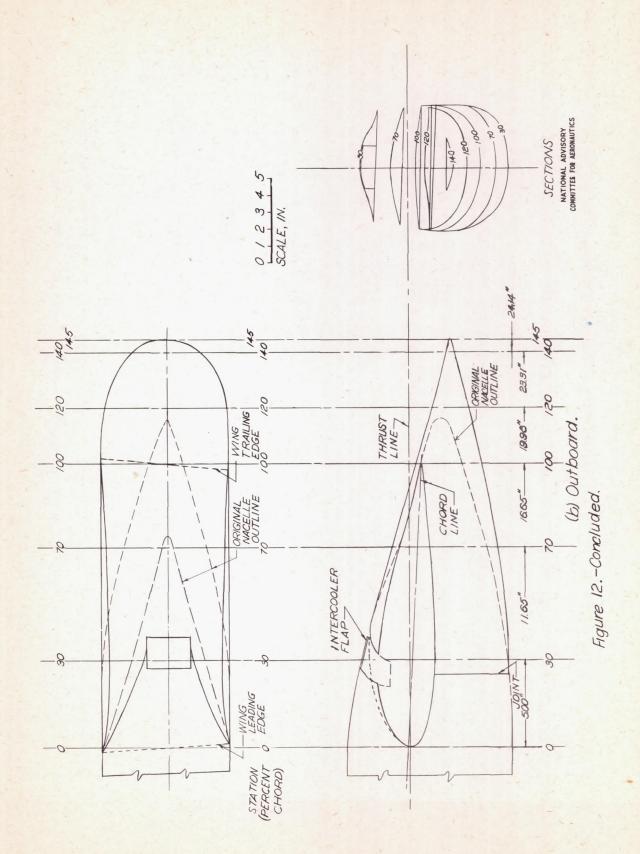
Figure 10.- Nacelle afterbody 5. $\delta_f = 0°$.

STATION
(PERCENT
CHORD)

WING LEADING EDGE

ORIGINAL NACELLE OUTLINE

WING TRAILING EDGE

0   18.1   80   100 110 120 128

3.73"   16.50"   20.63"   22.69" 24.76"

26.46"

INTERCOOLER FLAP

THRUST LINE

JOINT

ORIGINAL NACELLE OUTLINE

CHORD LINE

SCALE, IN.
0 1 2 3 4 5

SECTIONS

18.1
80
100
120
110
80
18.1

Figure 11.- Inboard nacelle afterbody 3.

Fig. 11

0   40   70   100   120 130 132.4

STATION
(PERCENT
CHORD)

WING
LEADING
EDGE

WING
TRAILING
EDGE

ORIGINAL
NACELLE
OUTLINE

0 1 2 3 4 5

SCALE, IN.

0   40   70   100   120 130 132.4

8.25"   14.44"   20.63"   24.76"   26.88"

27.32"

INTERCOOLER
FLAP

THRUST
LINE

CHORD
LINE

JOINT

ORIGINAL
NACELLE
OUTLINE

0   40   70   100   120 130 132.4

70

130
120
100
70
40

SECTIONS

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(a) Inboard.

Figure 12.- Nacelle afterbody 4.

Figure 12.-Concluded.

(b) Outboard.

STATION (PERCENT CHORD)

WING LEADING EDGE

WING TRAILING EDGE

ORIGINAL NACELLE OUTLINE

INTERCOOLER FLAP

THRUST LINE

CHORD LINE

JOINT

ORIGINAL NACELLE OUTLINE

SCALE, IN.

SECTIONS

(a) Inboard.

Figure 13.— Nacelle afterbody 5.

STATION
(PERCENT EDGE
CHORD) 0

WING LEADING EDGE

ORIGINAL NACELLE OUTLINE

WING TRAILING EDGE

INTERCOOLER FLAP

THRUST LINE

CHORD LINE

JOINT

(b) Outboard.

Figure 13.—Concluded.

0 1 2 3 4 5
SCALE, IN.

SECTIONS

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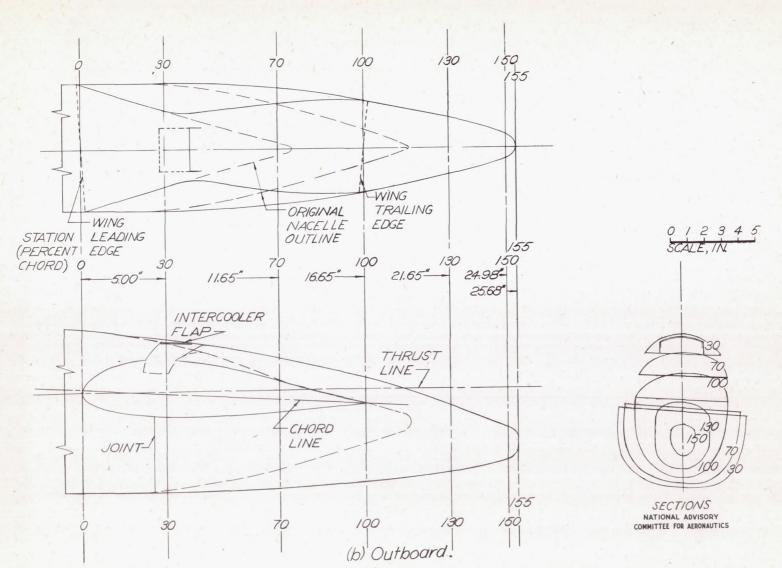
Figure 14.- Inboard nacelle afterbody 4. $\delta_f = 40^\circ$.

Figure 15.- Inboard nacelle afterbody 5. $\delta_f = 40°$.
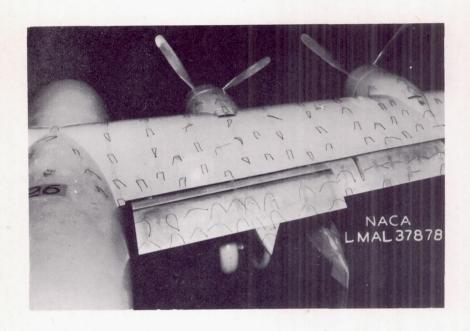
Figure 16.- Double slotted inboard flap.
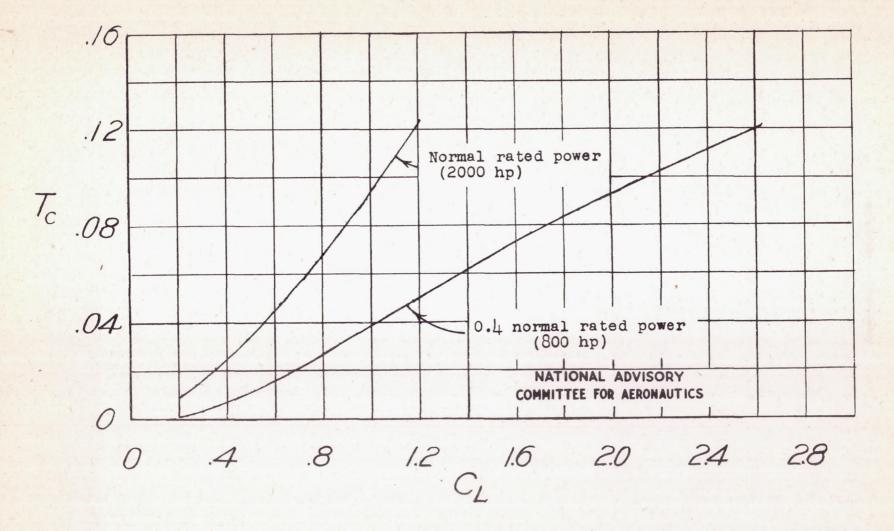
Figure 17.- Calculated thrust coefficient for one engine. Sea-level conditions.

Fig. 17

(a) Transition fixed;
    0.4 normal rated power.

(b) Natural transition;
    0.4 normal rated power.

(c) Transition fixed;
    propellers off.
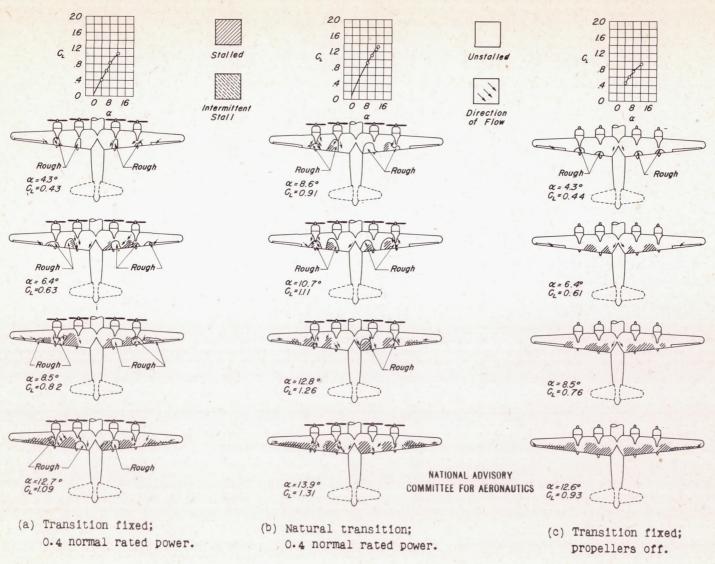
Figure 18.- Stall studies of model in standard configuration. $\delta_f = 0°$; cowl and intercooler flaps closed; $R \approx 2,600,000$.

(a) Leading-edge gloves.

(b) $1\frac{1}{2}$-inch-chord 0.3-span trailing-edge extensions.

(c) $1\frac{1}{2}$-inch-chord 0.6-span trailing-edge extensions.

(d) $2\frac{1}{4}$-inch-chord 0.6-span trailing-edge extensions.

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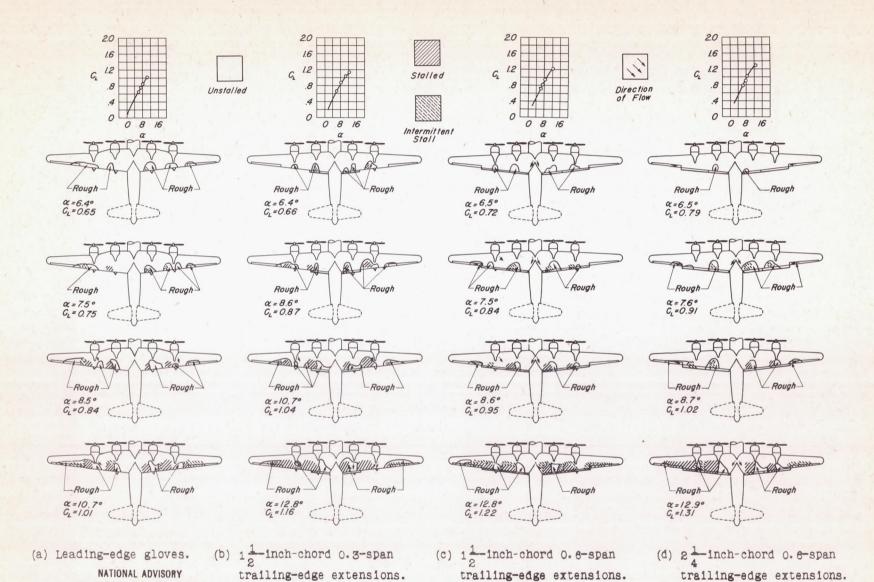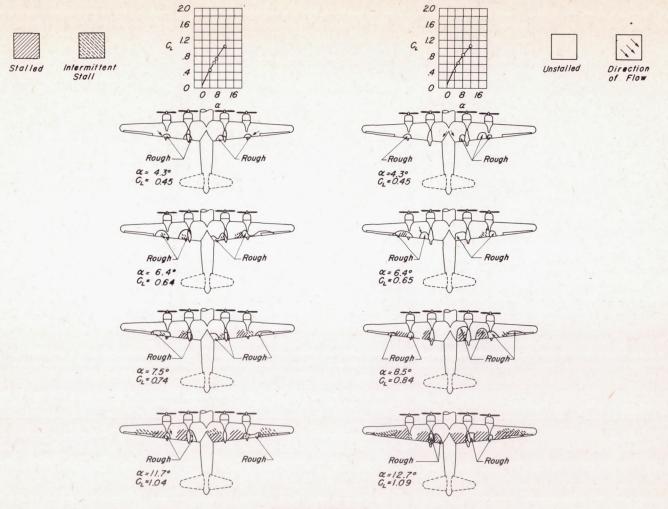
Figure 19.- Stall studies with leading-edge gloves and trailing-edge extensions. $\delta_f = 0°$; cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.

(a) Afterbodies 2.

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(b) Afterbodies 3.

Figure 20.- Stall studies with modified inboard afterbodies 2 and 3. $\delta_f = 0°$; cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

Stalled

Intermittent Stall

$\alpha = 6.4°$
$C_L = 0.69$
Rough   Rough

$\alpha = 7.5°$
$C_L = 0.80$
Rough   Rough

$\alpha = 8.6°$
$C_L = 0.90$
Rough   Rough

$\alpha = 12.8°$
$C_L = 1.20$
Rough   Rough

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

Unstalled

Direction of Flow

$\alpha = 6.5°$
$C_L = 0.79$
Rough   Rough

$\alpha = 7.6°$
$C_L = 0.91$
Rough   Rough

$\alpha = 8.7°$
$C_L = 1.03$
Rough   Rough

$\alpha = 12.9°$
$C_L = 1.33$
Rough   Rough

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

$\alpha = 6.5°$
$C_L = 0.80$
Rough   Rough

$\alpha = 7.6°$
$C_L = 0.93$
Rough   Rough

$\alpha = 8.7°$
$C_L = 1.04$
Rough   Rough

$\alpha = 12.9°$
$C_L = 1.38$
Rough   Rough

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(a) Leading-edge gloves.

(b) Trailing-edge extensions.

(c) Leading-edge gloves and trailing-edge extensions.

Figure 21.- Stall studies with afterbodies 4 and chord extensions. $\delta_f = 0°$; cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.

(a) Leading-edge gloves.   (b) Trailing-edge extensions.   (c) Leading-edge gloves and trailing-edge extensions.
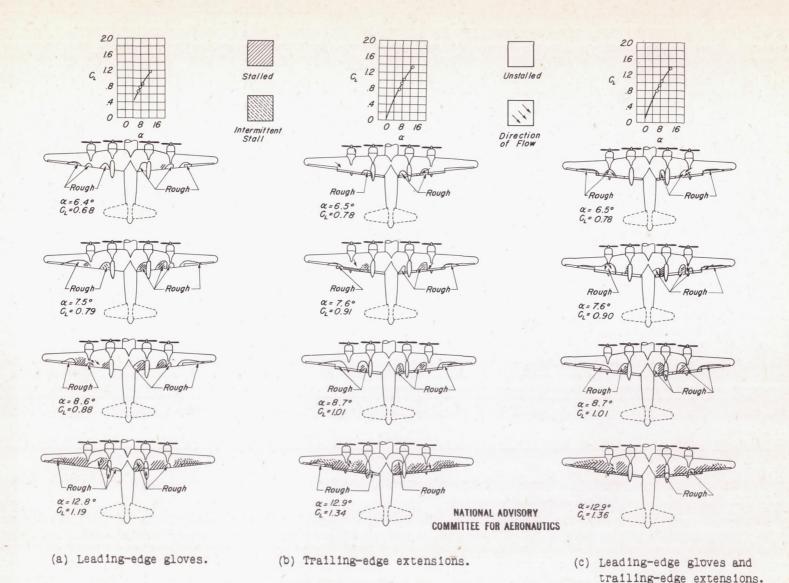
Figure 22.- Stall studies with afterbodies 5 and chord extensions. $\delta_f = 0°$; cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.
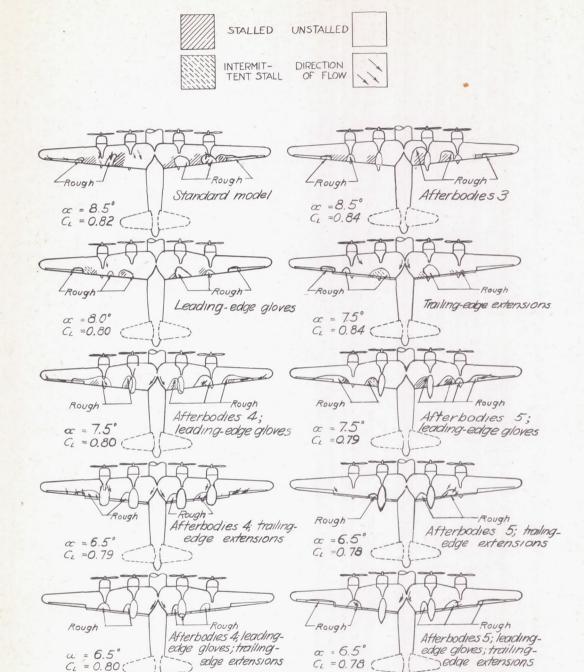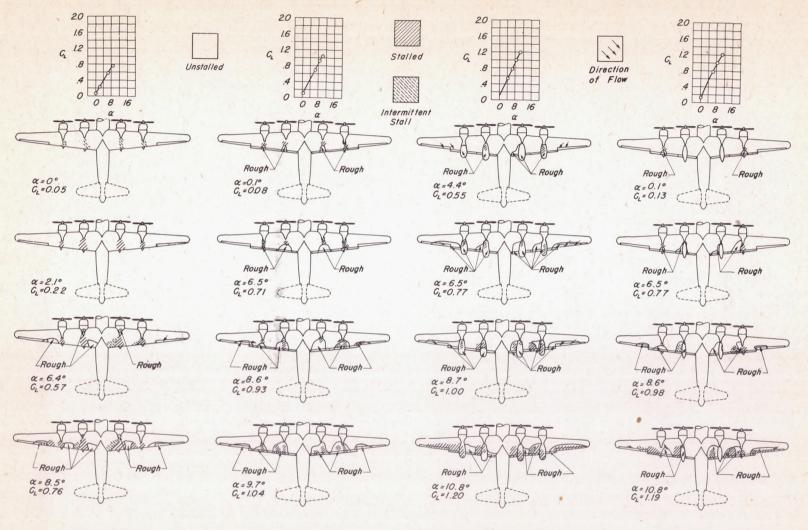
Figure 23. —Comparison of stall patterns with standard and modified model at a lift coefficient of approximately 0.8. $\delta_f = 0°$; cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

☐ Unstalled

$\alpha = 0°$
$C_L = 0.05$

$\alpha = 2.1°$
$C_L = 0.22$

Rough — — Rough
$\alpha = 6.4°$
$C_L = 0.57$

Rough — — Rough
$\alpha = 8.5°$
$C_L = 0.76$

(a) Standard model.

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

▨ Stalled

▨ Intermittent Stall

Rough — — Rough
$\alpha = 0.1°$
$C_L = 0.08$

Rough — — Rough
$\alpha = 6.5°$
$C_L = 0.71$

Rough — — Rough
$\alpha = 8.6°$
$C_L = 0.93$

Rough — — Rough
$\alpha = 9.7°$
$C_L = 1.04$

(b) Trailing-edge extensions.

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

▨ Direction of Flow

Rough — — Rough
$\alpha = 4.4°$
$C_L = 0.55$

Rough — — Rough
$\alpha = 6.5°$
$C_L = 0.77$

Rough — — Rough
$\alpha = 8.7°$
$C_L = 1.00$

Rough — — Rough
$\alpha = 10.8°$
$C_L = 1.20$

(c) Afterbodies 4 and trailing-edge extensions.

2.0
1.6
C_L 1.2
.8
.4
0
0 8 16
α

Rough — — Rough
$\alpha = 0.1°$
$C_L = 0.13$

Rough — — Rough
$\alpha = 6.5°$
$C_L = 0.77$

Rough — — Rough
$\alpha = 8.6°$
$C_L = 0.98$

Rough — — Rough
$\alpha = 10.8°$
$C_L = 1.19$

(d) Inboard afterbodies 5 and trailing-edge extensions.

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Figure 24.- Stall studies of standard and modified models. $\delta_f = 0°$; cowl and inter-cooler flaps open; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.

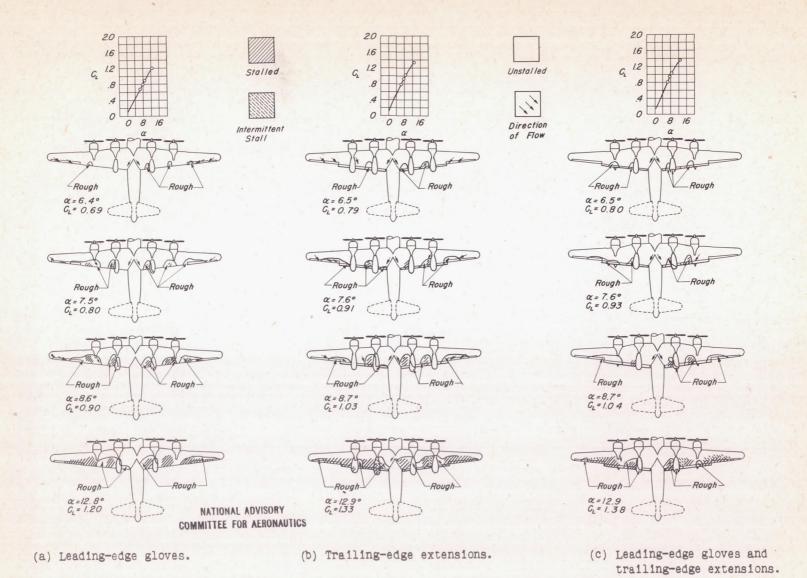Stalled   Intermittent Stall   Unstalled   Direction of Flow

α = 4.4°
$C_L = 0.66$

α = 5.2°
$C_L = 1.78$

α = 6.6°
$C_L = 0.88$

α = 8.4°
$C_L = 2.20$

α = 8.7°
$C_L = 1.11$

α = 12.7°
$C_L = 2.52$

α = 10.8°
$C_L = 1.28$

α = 13.7°
$C_L = 2.57$

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(a) $\delta_f = 10°$.   (b) $\delta_f = 40°$.

Figure 25.- Stall studies of standard model with wing flaps deflected. Cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; R ≈ 2,600,000.

Stalled   Intermittent   Unstalled   Direction
           Stall   of Flow

Rough

Rough — Rough

Rough

Stalled   Stalled on left flap   Stalled
                       Rough on right flap.

Unstalled   Unstalled

(a) Standard model;   (b) Double slotted flap;   (c) Afterbodies 4; flap
    $\alpha = 11.6^{O}$. $\alpha = 11.6^{O}$.   continuous; $\alpha = 11.6^{O}$.

Rough   Rough   Rough

Smooth flow   Smooth flow   Smooth flow

(d) Afterbodies 4; flaps cut   (e) Afterbodies 5; $\alpha = 11.8^{O}$.   (f) Afterbodies 5; trailing-
    out at nacelle; $\alpha = 11.8^{O}$.   edge extensions cut out;
                                                                              $\alpha = 11.8^{O}$.

Figure 26.- Flow over inboard flaps and afterbodies. $\delta_f = 40^{O}$; cowl and inter-
cooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.

Unstalled

Stalled

Intermittent Stall

Direction of Flow

C_L 2.8 2.4 2.0 1.6 1.2 .8   0 8 16 α

C_L 2.8 2.4 2.0 1.6 1.2 .8   0 8 16 α

C_L 3.0 2.6 2.2 1.8 1.4 1.0   0 8 16 α

C_L 3.0 2.6 2.2 1.8 1.4   0 8 16 α

Rough   Rough
$\alpha = 5.1°$
$C_L = 1.72$

Rough   Rough
$\alpha = 5.3°$
$C_L = 2.02$

Rough   Rough
$\alpha = 5.2°$
$C_L = 1.81$

Rough   Rough
$\alpha = 5.4°$
$C_L = 2.20$

Rough   Rough
$\alpha = 9.4°$
$C_L = 2.20$

Rough   Rough
$\alpha = 9.6°$
$C_L = 2.49$

Rough   Rough
$\alpha = 9.5°$
$C_L = 2.35$

Rough   Rough
$\alpha = 9.8°$
$C_L = 2.70$

Rough   Rough
$\alpha = 11.6°$
$C_L = 2.38$

Rough
$\alpha = 11.7°$
$C_L = 2.63$

Rough   Rough
$\alpha = 11.6°$
$C_L = 2.52$

Rough
$\alpha = 11.8°$
$C_L = 2.81$

Rough   Rough
$\alpha = 13.6°$
$C_L = 2.46$

$\alpha = 13.8°$
$C_L = 2.72$

Rough   Rough
$\alpha = 13.7°$
$C_L = 2.58$

Rough
$\alpha = 13.9°$
$C_L = 2.90$

(a) Afterbodies 4; flaps cut out.

(b) Afterbodies 4; flaps and trailing-edge extensions cut out.

(c) Afterbodies 5.

(d) Afterbodies 5; trailing-edge extensions cut out.

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Figure 27.- Stall studies of modified model. $\delta_f = 40°$; cowl and intercooler flaps closed; 0.4 normal rated power; transition fixed; $R \approx 2,600,000$.
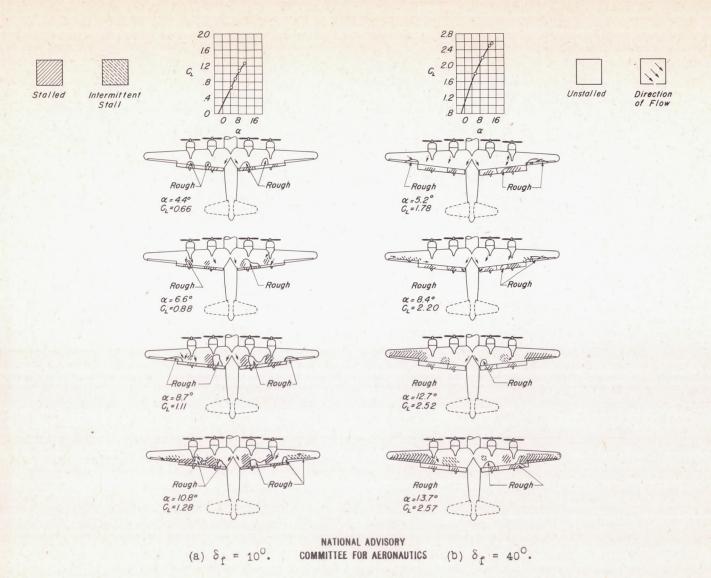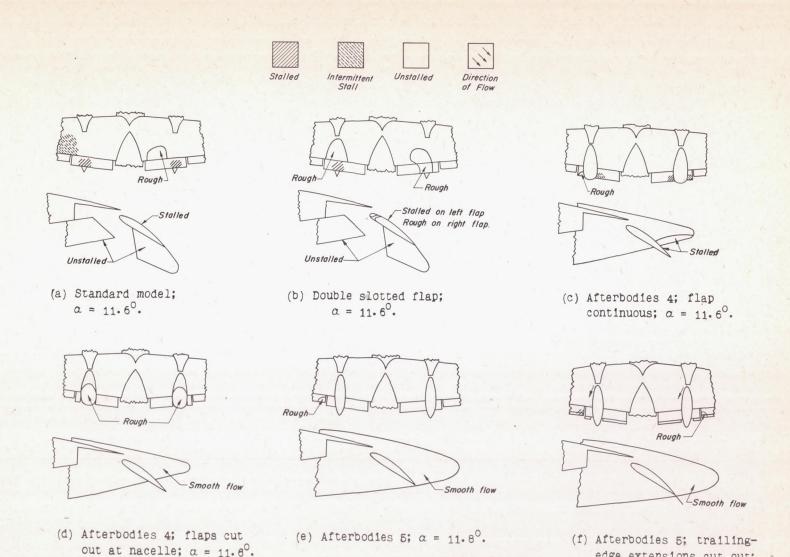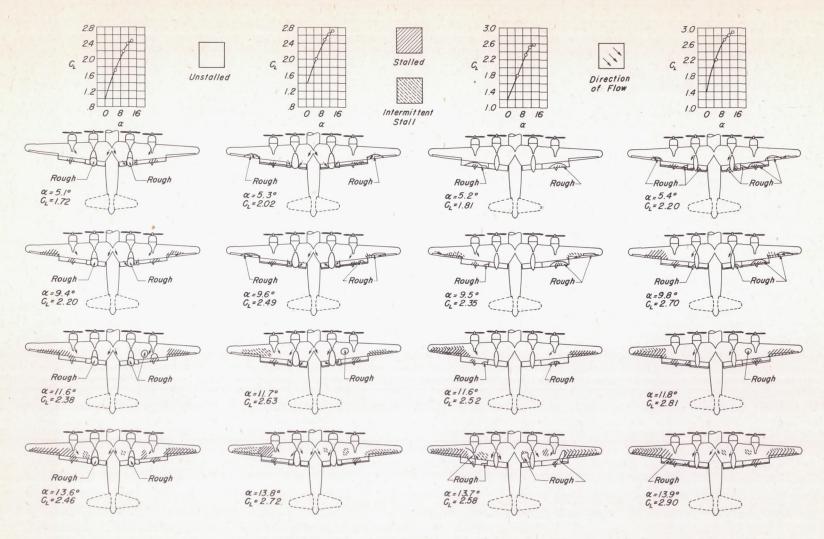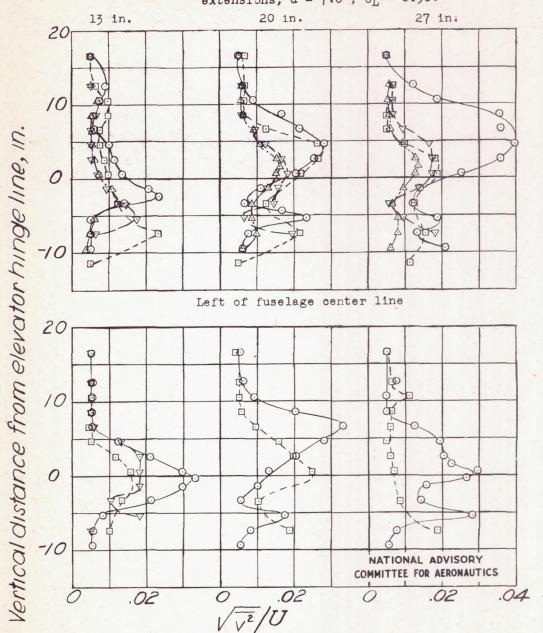
o Standard configuration; $\alpha = 7.5°$; $C_L = 0.73$
△ Inboard afterbodies 4 and trailing-edge extensions; $\alpha=7.6°$; $C_L=0.91$
□ Inboard afterbodies 5 and trailing-edge extensions; $\alpha=7.6°$; $C_L=0.91$
▽ Leading-edge gloves, inboard afterbodies 5, and trailing-edge
            extensions; $\alpha = 7.6°$; $C_L = 0.90$.

13 in.   20 in.   27 in.

Left of fuselage center line

$\sqrt{\overline{v^2}}/U$

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Right of fuselage center line
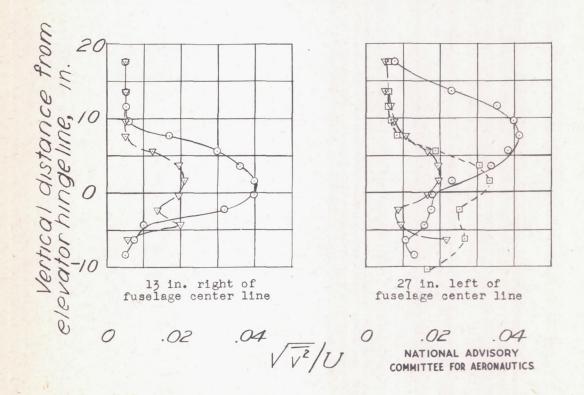
(a) $\alpha \approx 7.6°$.

Figure 28.- Vertical velocity deviations in region of horizontal
    tail for standard and modified models. $\delta_f = 0°$; cowl and
    intercooler flaps closed; transition fixed; 0.4 normal
    rated power; $R \approx 2,600,000$.

Vertical distance from elevator hinge line, in.

o Standard configuration; $\alpha = 8.5°$; $c_L = 0.82$
□ Inboard afterbodies 5 and trailing-edge extensions; $\alpha=8.7°$; $c_L=1.01$
▽ Leading-edge gloves, inboard afterbodies 5, and trailing-edge
        extensions; $\alpha = 8.7°$; $c_L = 1.01$

13 in. right of   27 in. left of
fuselage center line   fuselage center line

$\sqrt{\overline{v^2}}/U$ NATIONAL ADVISORY
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(b) $\alpha \approx 8.7°$.

Figure 28.- Concluded.

(a) Standard configuration.

	α (deg)	C_L
△	4.3	0.43
○	7.5	.73
▽	8.5	.82

(b) Inboard afterbodies 5 and trailing-edge extensions.

	α (deg)	C_L
△	4.4	0.56
○	7.6	.91
▽	8.7	1.01

$\sqrt{\overline{v^2}}/U$

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Figure 29.- Effect of angle of attack on vertical velocity deviations in region of horizontal tail for standard and modified models. $\delta_f = 0°$; cowl and intercooler flaps closed; transition fixed; 0.4 normal rated power; R ≈ 2,600,000.
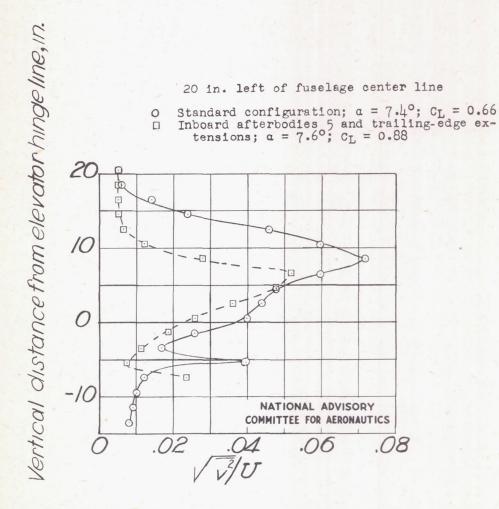
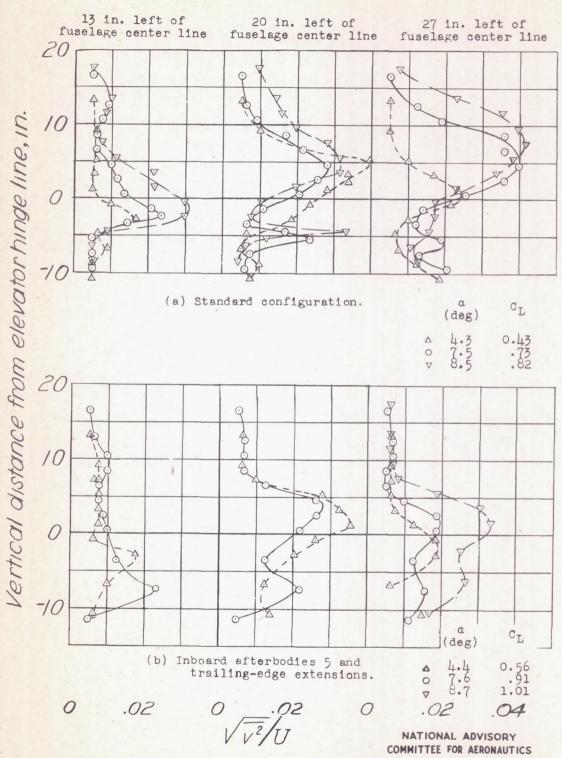Figure 30.- Vertical velocity deviations in region of horizontal
tail for standard and modified models. $\delta_f = 0°$; cowl and
intercooler flaps open; transition fixed; 0.4 normal rated
power; $R \approx 2,600,000$.

Vertical distance from elevator hinge line, in.

(a) Standard configuration.
$\alpha = 12.7^\circ$; $C_L = 2.52$.

(b) Inboard afterbodies 4,
flap continuous.
$\alpha = 12.7^\circ$; $C_L = 2.51$.

(c) Inboard afterbodies 5.
$\alpha = 12.7^\circ$; $C_L = 2.55$.

Distance left of fuselage center line
(in.)
□   17
○   20
◇   23

(d) Leading-edge gloves,
inboard afterbodies 5,
and trailing-edge
extensions. $\alpha = 12.9^\circ$;
$C_L = 2.95$.

0   .02   .04   0   .02   .04
$\sqrt{\overline{v^2}}/U$

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Figure 31.- Vertical velocity deviations in region of horizontal
tail for standard and modified models. $\delta_f = 40^\circ$; cowl and
intercooler flaps closed; transition fixed; 0.4 normal rated
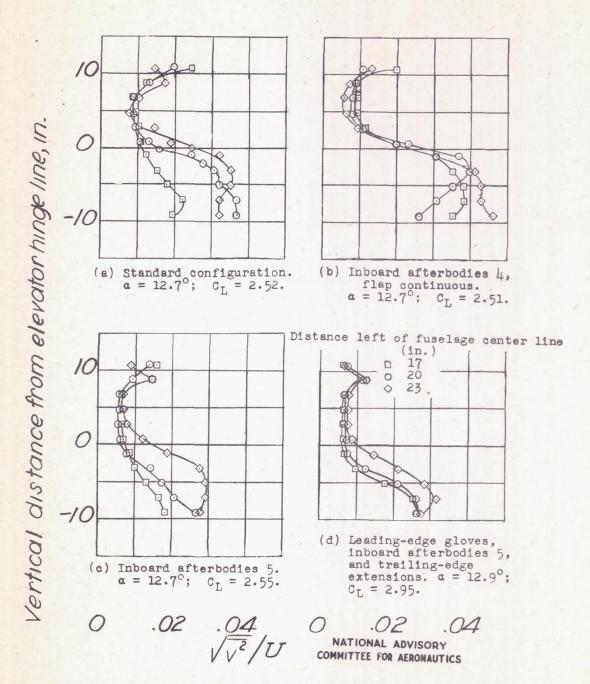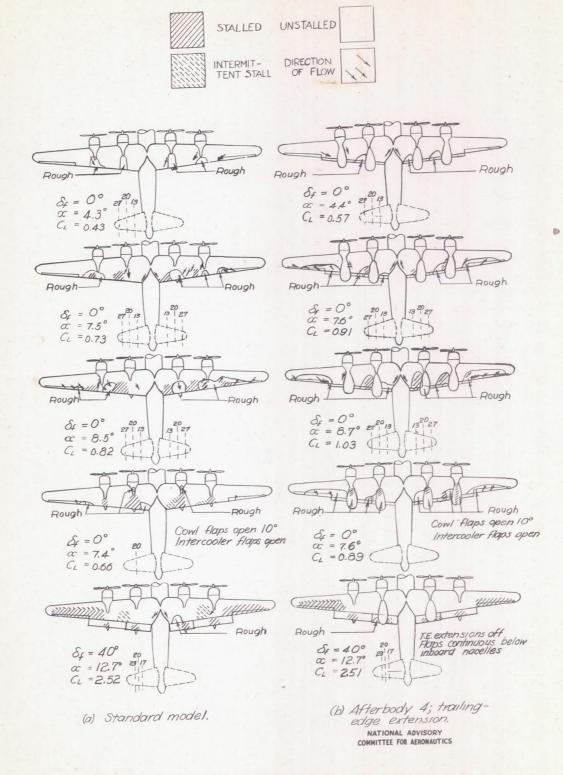power; $R \approx 2,600,000$.

STALLED   UNSTALLED

INTERMIT-   DIRECTION
TENT STALL   OF FLOW

$\delta_f = 0°$
$\alpha = 4.3°$
$C_L = 0.43$

$\delta_f = 0°$
$\alpha = 4.4°$
$C_L = 0.57$

$\delta_f = 0°$
$\alpha = 7.5°$
$C_L = 0.73$

$\delta_f = 0°$
$\alpha = 7.6°$
$C_L = 0.91$

$\delta_f = 0°$
$\alpha = 8.5°$
$C_L = 0.82$

$\delta_f = 0°$
$\alpha = 8.7°$
$C_L = 1.03$

Cowl flaps open 10°
Intercooler flaps open

$\delta_f = 0°$
$\alpha = 7.4°$
$C_L = 0.66$

$\delta_f = 0°$
$\alpha = 7.6°$
$C_L = 0.89$

Cowl flaps open 10°
Intercooler flaps open

$\delta_f = 40°$
$\alpha = 12.7°$
$C_L = 2.52$

$\delta_f = 40°$
$\alpha = 12.7°$
$C_L = 2.51$

T.E. extensions off
Flaps continuous below
inboard nacelles

(a) Standard model.

(b) Afterbody 4; trailing-
edge extension.

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Figure 32.- Stall patterns for conditions of
turbulence surveys. Transition fixed;
0.4 normal rated power; $R \approx 2,600,000$.

STALLED   UNSTALLED

INTERMIT-   DIRECTION
TENT STALL   OF FLOW

Rough   Rough

$\delta_f = 0°$
$\alpha = 4.4°$
$C_L = 0.56$

Rough   Rough

$\delta_f = 0°$
$\alpha = 7.6°$
$C_L = 0.91$

Rough   Rough

$\delta_f = 0°$
$\alpha = 8.7°$
$C_L = 1.01$

Rough   Rough

Cowl flaps open 10°
Intercooler flaps open

$\delta_f = 0°$
$\alpha = 7.6°$
$C_L = 0.88$

Rough   Rough

T.E. extensions off

$\delta_f = 40°$
$\alpha = 12.7°$
$C_L = 2.55$

Rough   Rough

$\delta_f = 0°$
$\alpha = 44°$
$C_L = 0.55$

Rough   Rough

$\delta_f = 0°$
$\alpha = 7.6°$
$C_L = 0.90$

Rough   Rough

$\delta_f = 0°$
$\alpha = 8.7°$
$C_L = 1.01$

Rough   Rough

T.E. extensions out
at inboard nacelles

$\delta_f = 40°$
$\alpha = 12.9°$
$C_L = 2.95$

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(c) Afterbodies 5; trailing-
edge extension.

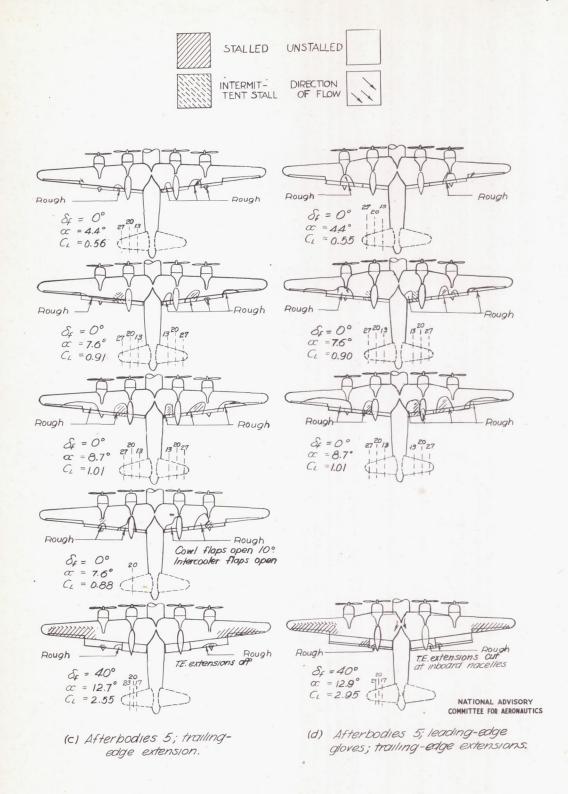(d) Afterbodies 5; leading-edge
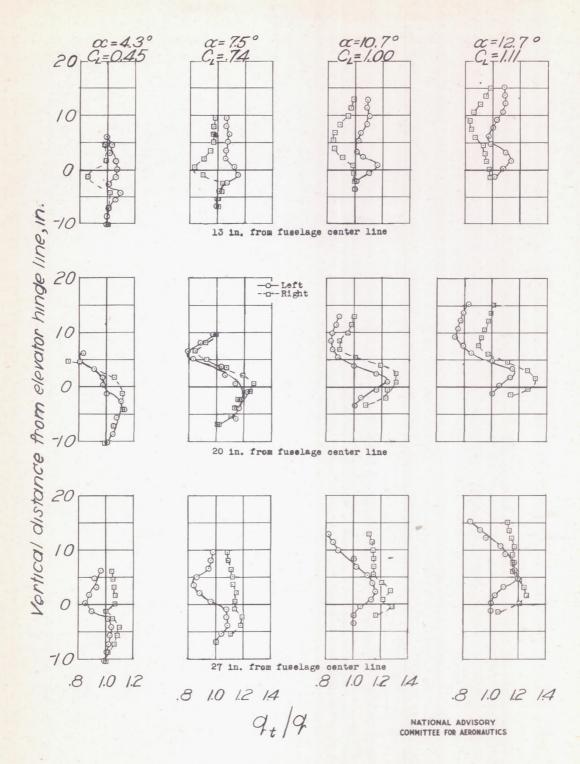gloves; trailing-edge extensions.

Figure 32.- Concluded.

Figure 33.- Dynamic-pressure variation in the region of the horizontal tail.
Standard configuration; $\delta_f = 0°$; cowl and intercooler flaps closed; transition
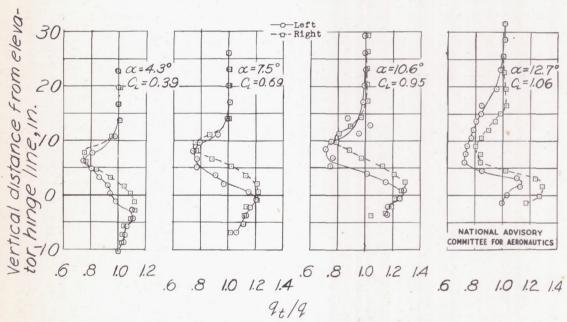fixed; 0.4 normal rated power; R ≈ 2,600,000.

Figure 34.- Dynamic-pressure variation in the region of the horizontal tail, 20 inches from fuselage center line. Standard configuration; $\delta_f = 0°$; cowl and intercooler flaps open; transition fixed; 0.4 normal rated power; $R \approx 2,600,000$.
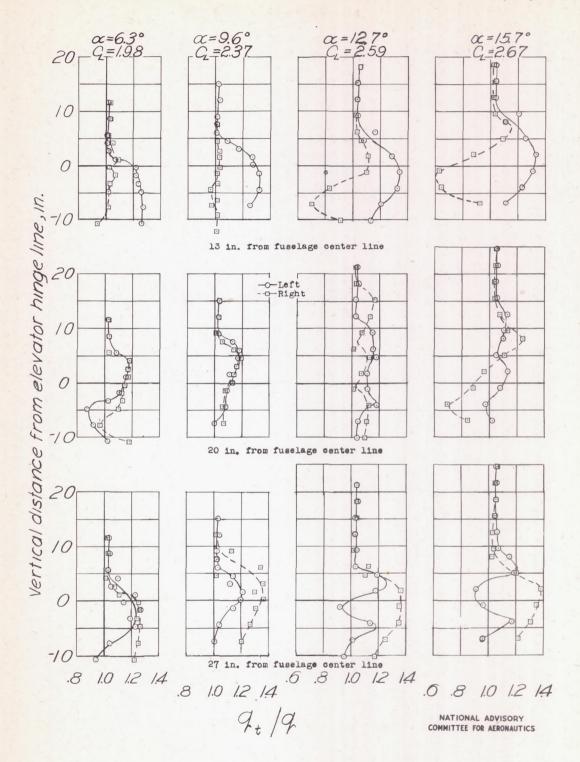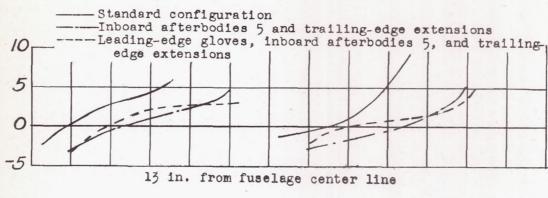
Figure 35.- Dynamic-pressure variation in the region of the horizontal tail.
Standard configuration; $\delta_f \approx 40°$; cowl and intercooler flaps closed; transition
fixed; 0.4 normal rated power; R ≈ 2,600,000.

Standard configuration
Inboard afterbodies 5 and trailing-edge extensions
Leading-edge gloves, inboard afterbodies 5, and trailing-
edge extensions

13 in. from fuselage center line

Left   Right

20 in. from fuselage center line

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27 in. from fuselage center line

C_L

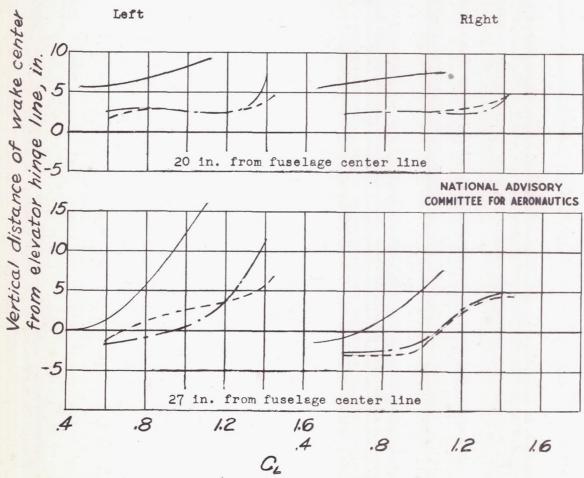Vertical distance of wake center from elevator hinge line, in.

Figure 36.- Variation of location of dynamic-pressure wake
center with lift coefficient. $\delta_f = 0°$; cowl and intercooler
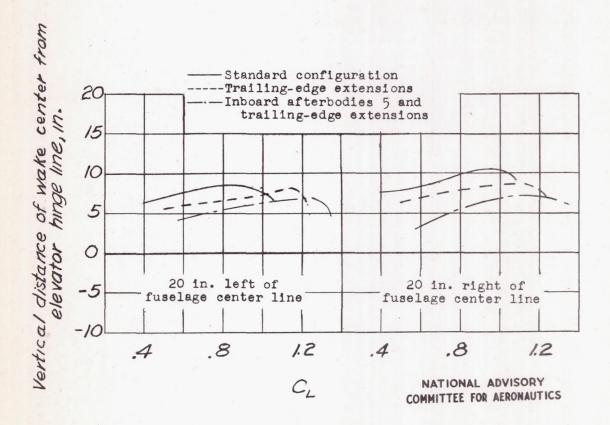flaps closed; transition fixed; 0.4 normal rated power;
$R \approx 2,600,000$.

Figure 37.- Variation of location of dynamic-pressure wake center with lift coefficient. $\delta_f = 0°$; cowl and intercooler flaps open; transition fixed; 0.4 normal rated power; $R \approx 2,600,000$.
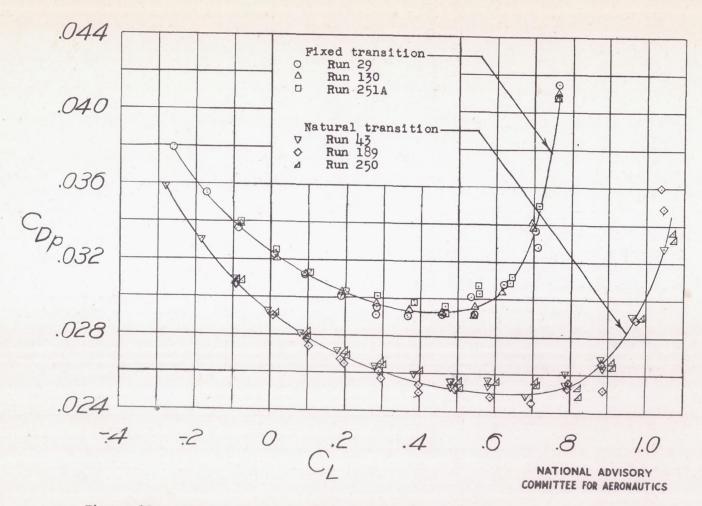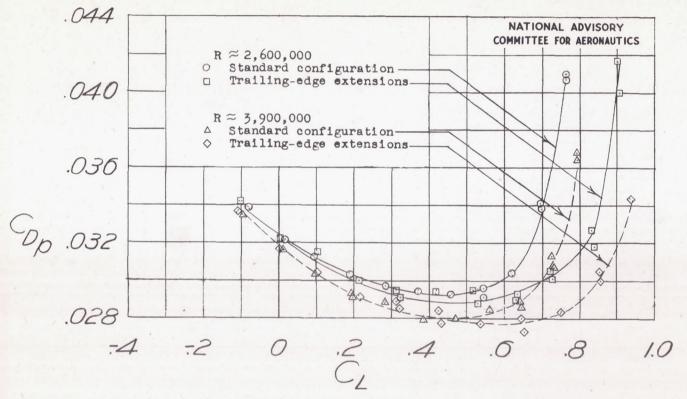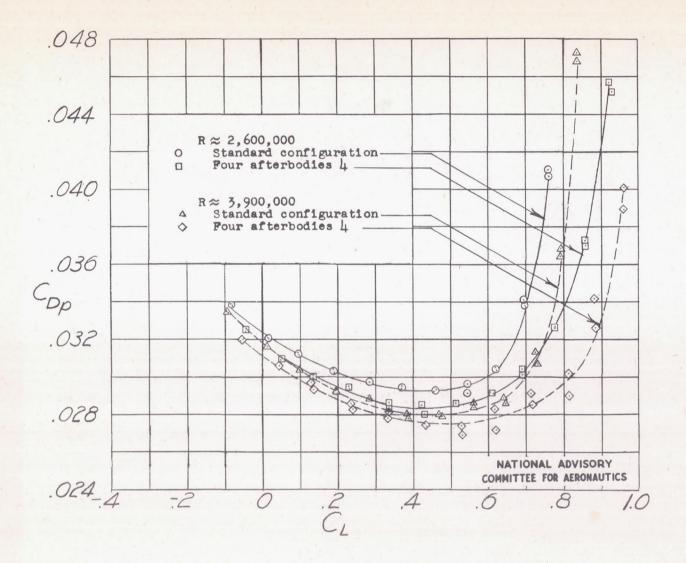
Figure 38 .- Drag characteristics obtained from several runs with model in the standard configuration. $\delta_f = 0°$; cowl and intercooler flaps closed; $R \approx 2,600,000$.

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Fig. 38
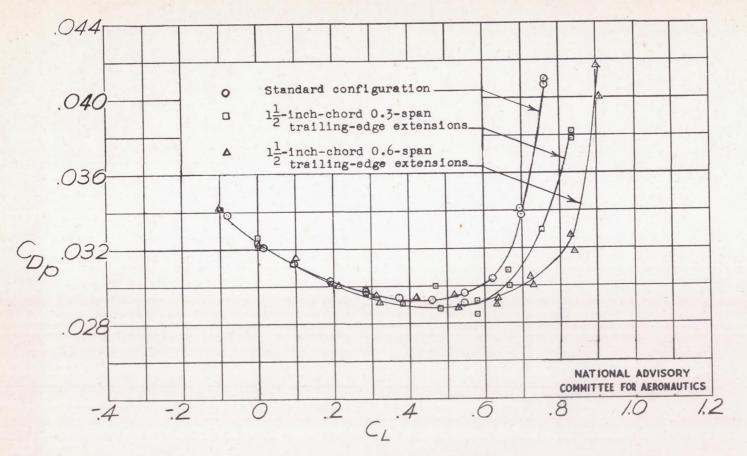
(a) Trailing-edge extensions having $1\frac{1}{2}$-inch chord and 0.6 span.

Figure 39.- Drag characteristics at two Reynolds numbers for standard and modified
models. $\delta_f = 0°$; cowl and intercooler flaps closed; fixed transition.

R ≈ 2,600,000
O   Standard configuration
□   Four afterbodies 4

R ≈ 3,900,000
△   Standard configuration
◇   Four afterbodies 4

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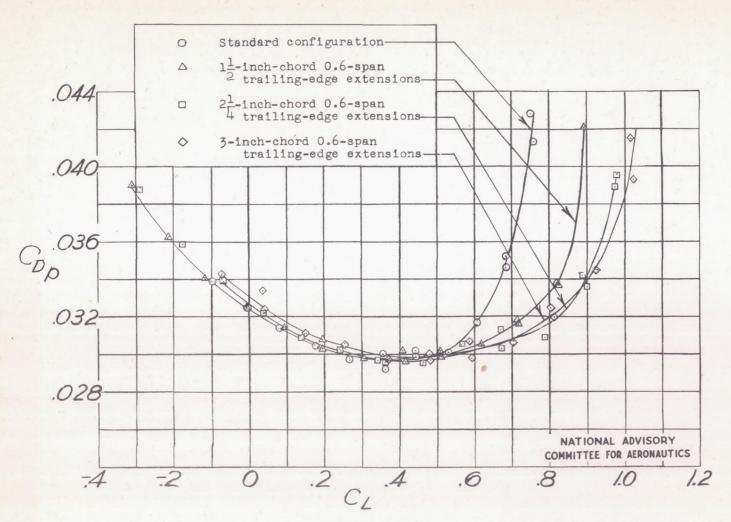
(b) Modified afterbodies.

Figure 39 .- Concluded.
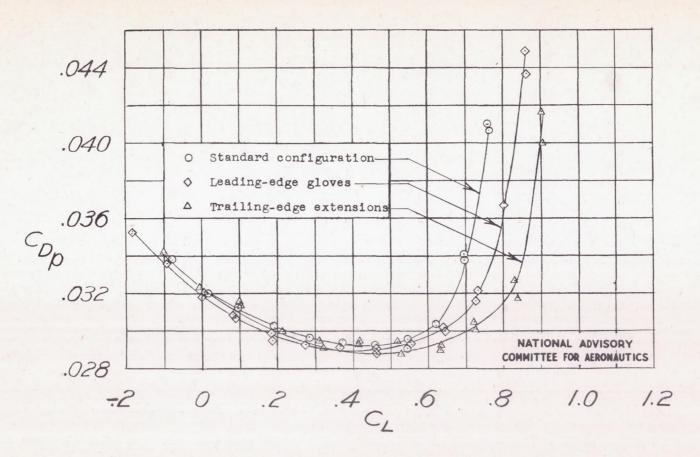
(a) Effect of span.

Figure 40.- Drag characteristics with several trailing-edge extensions. $\delta_f = 0°$; cowl and intercooler flaps closed; fixed transition; $R \approx 2,600,000$.

Legend:
- ○ Standard configuration
- △ $1\frac{1}{2}$-inch-chord 0.6-span trailing-edge extensions
- □ $2\frac{1}{4}$-inch-chord 0.6-span trailing-edge extensions
- ◇ 3-inch-chord 0.6-span trailing-edge extensions

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(b) Effect of chord.

Figure 40 .- Concluded.

.044

.040

.036

C_{Dp}

.032

.028

O   Standard configuration
◇   Leading-edge gloves
△   Trailing-edge extensions

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-.2   0   .2   .4   .6   .8   1.0   1.2

C_L

(a) Fixed transition.

Figure 41 .- Drag characteristics with leading-edge gloves and trailing-edge ex-
tensions. $\delta_f = 0°$; cowl and intercooler flaps closed; $R \approx 2,600,000$.

○ Standard configuration
◇ Leading-edge gloves
△ Trailing-edge extensions
□ Leading-edge gloves and
   trailing-edge extensions

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(b) Natural transition.

Figure 41.- Concluded.
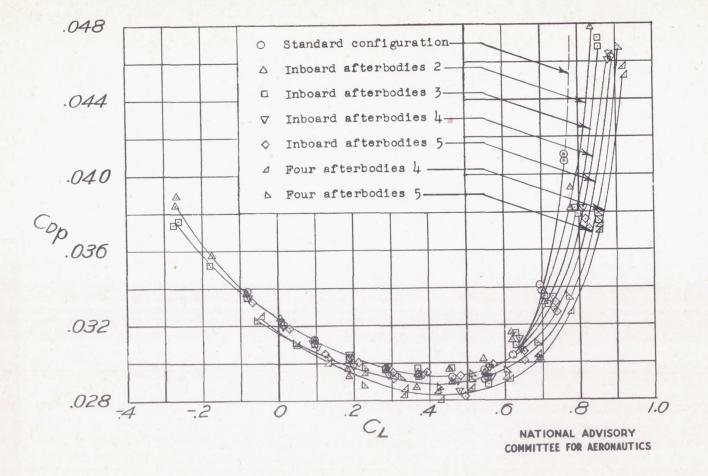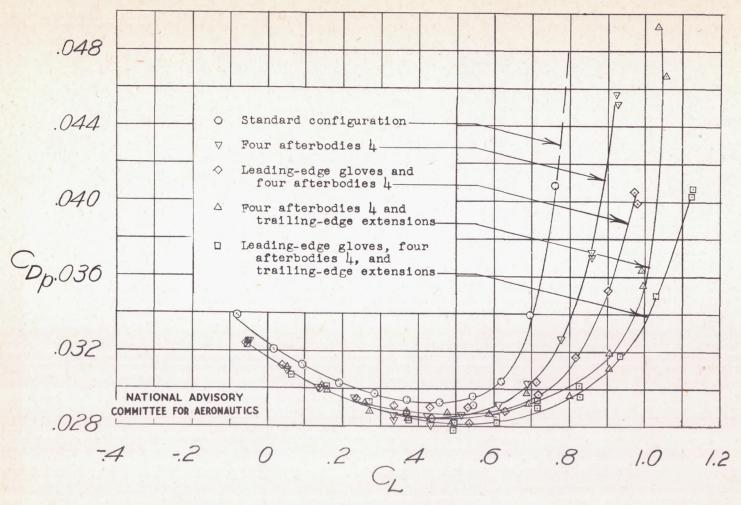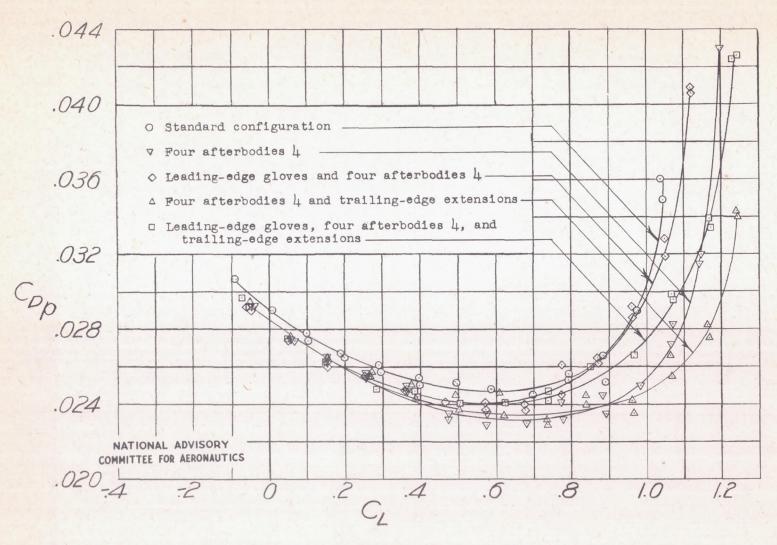
Figure 42.- Drag characteristics with modified afterbodies. $\delta_f = 0°$; cowl and intercooler flaps closed; fixed transition; $R \approx 2,600,000$.
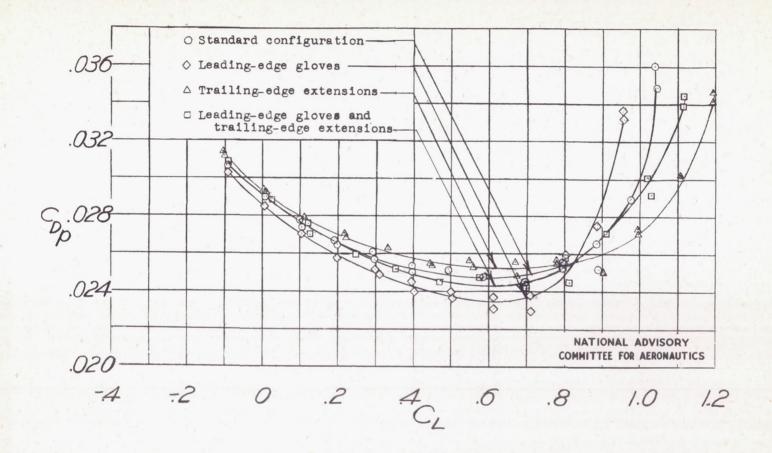
Fig. 42

.048

.044

C_{Dp} .036

○ Standard configuration

▽ Four afterbodies 4

◇ Leading-edge gloves and
   four afterbodies 4

△ Four afterbodies 4 and
   trailing-edge extensions

□ Leading-edge gloves, four
   afterbodies 4, and
   trailing-edge extensions

.040

.032

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.028

-.4   -.2   0   .2   .4   .6   .8   1.0   1.2

C_L

(a) Fixed transition.

Figure 43.- Drag characteristics with afterbodies 4 alone and with chord extensions.
$\delta_f = 0°$; cowl and intercooler flaps closed; $R \approx 2,600,000$.

Key / legend:
○ Standard configuration
▽ Four afterbodies 4
◇ Leading-edge gloves and four afterbodies 4
△ Four afterbodies 4 and trailing-edge extensions
□ Leading-edge gloves, four afterbodies 4, and trailing-edge extensions

C_{Dp}

C_L

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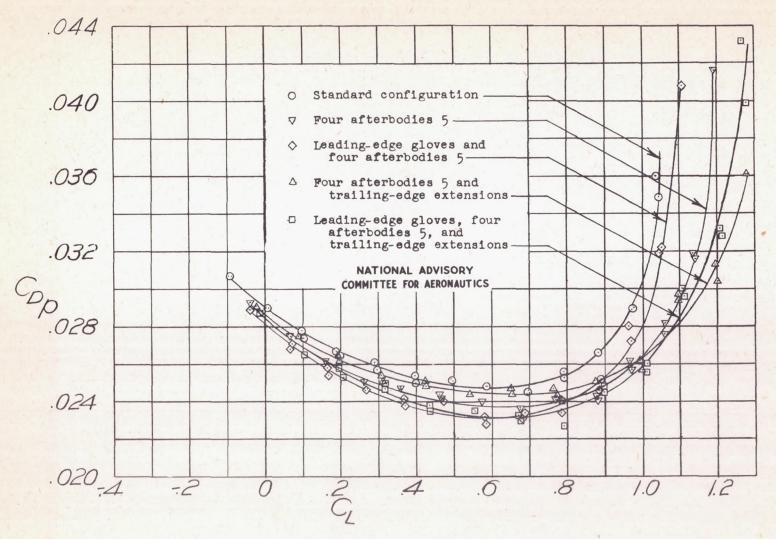
(b) Natural transition.

Figure 43.- Concluded.

O   Standard configuration
∇   Four afterbodies 5
◇   Leading-edge gloves and four afterbodies 5
△   Four afterbodies 5 and trailing-edge extensions
□   Leading-edge gloves, four afterbodies 5, and
      trailing-edge extensions

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(a) Fixed transition.

Figure 44.- Drag characteristics with afterbodies 5 alone and with chord extensions.
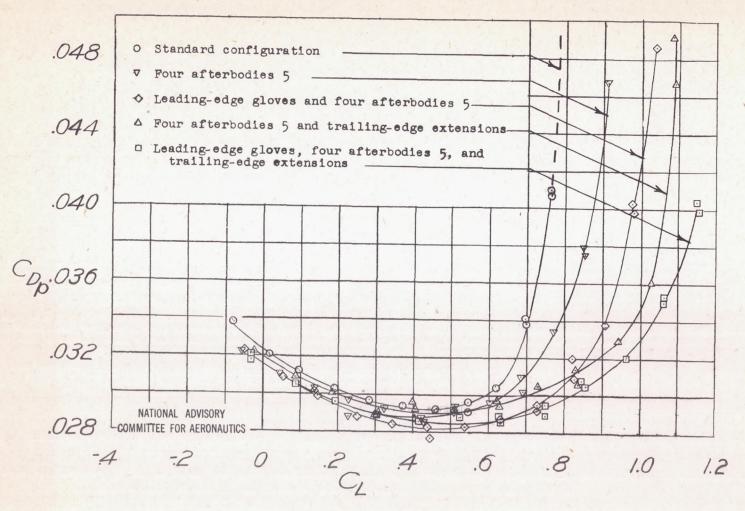$\delta_f = 0^\circ$; cowl and intercooler flaps closed; $R \approx 2,600,000$.

Standard configuration

Four afterbodies 5

Leading-edge gloves and four afterbodies 5

Four afterbodies 5 and trailing-edge extensions

Leading-edge gloves, four afterbodies 5, and trailing-edge extensions

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(b) Natural transition.

Figure 44.- Concluded.
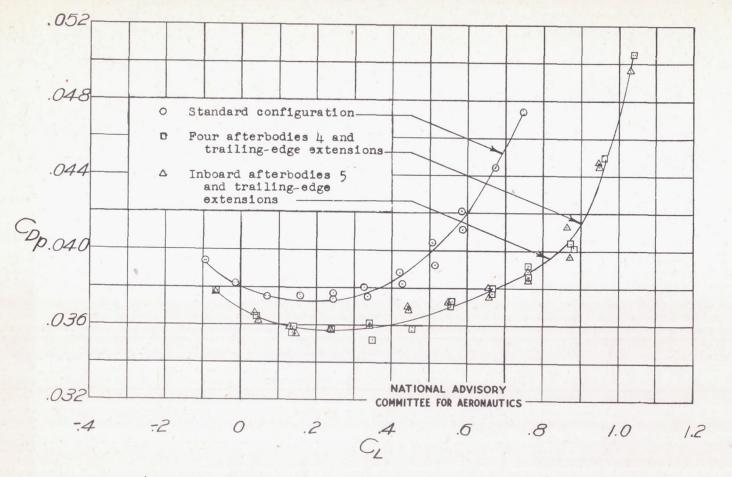
Figure 45.- Drag characteristics with cowl and intercooler flaps open for standard and modified models. $\delta_f = 0°$; fixed transition; $R \approx 2,600,000$.

Fig. 45
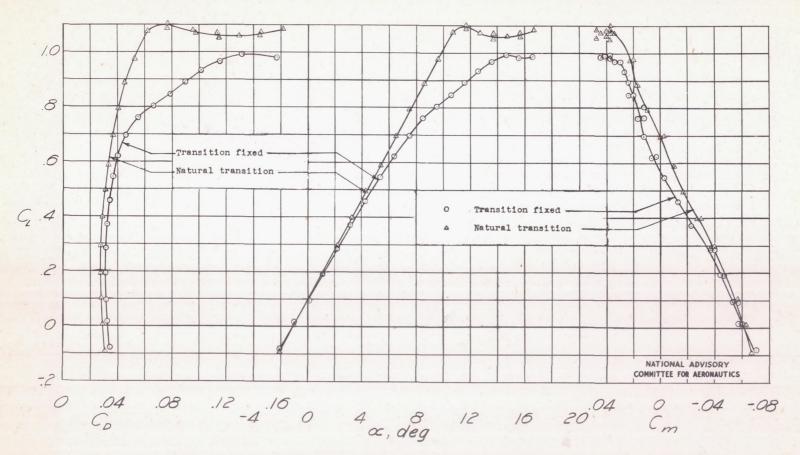
Figure 46.- Aerodynamic characteristics with fixed and natural transition. Standard configuration; $\delta_f = 0°$; cowl and intercooler flaps closed; $R \approx 2,600,000$; propellers off.

Fig. 46
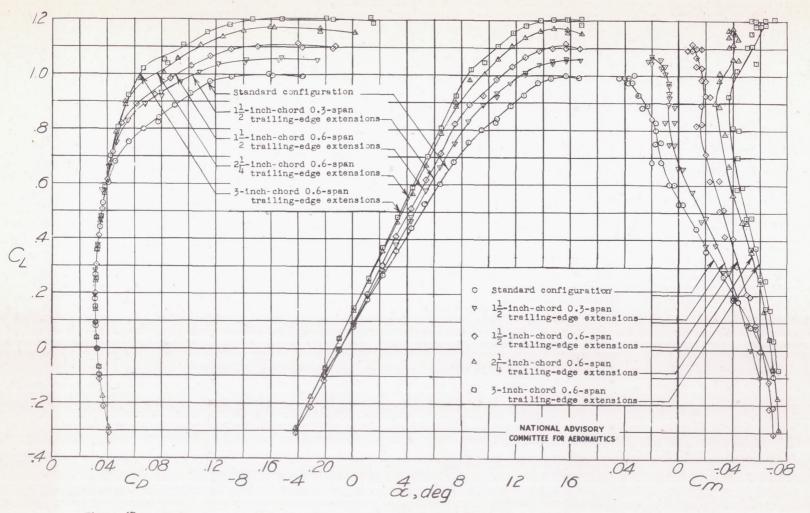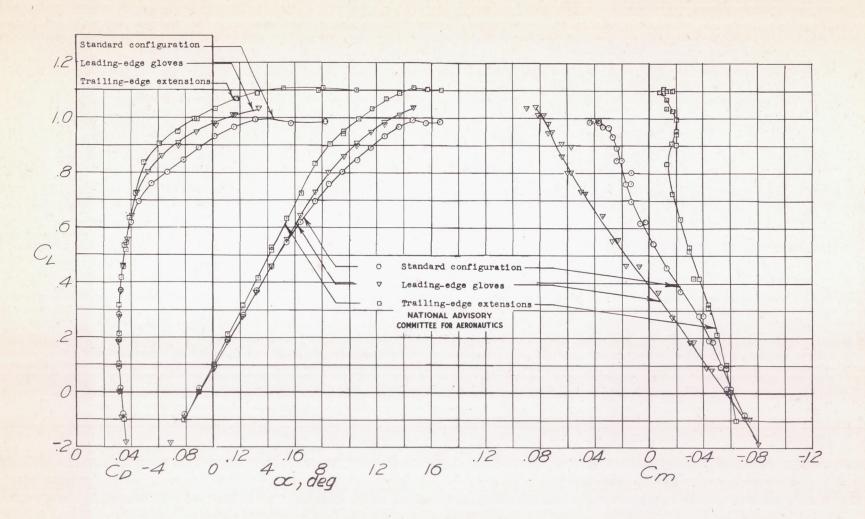
Figure 47.- Aerodynamic characteristics with several trailing-edge extensions. $\delta_f = 0°$; cowl and intercooler flaps closed; fixed transition; $R \approx 2,600,000$; propellers off.

Fig. 47

Standard configuration
Leading-edge gloves
Trailing-edge extensions

C_L

o   Standard configuration
▽   Leading-edge gloves
□   Trailing-edge extensions

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C_D α, deg C_m

(a) Fixed transition.

Figure 48 .- Aerodynamic characteristics with leading-edge gloves and trailing-edge extensions. $\delta_f = 0°$;
cowl and intercooler flaps closed; R ≈ 2,600,000; propellers off.

Trailing-edge extensions

Leading-edge gloves and

trailing-edge extensions

Standard configuration

Leading-edge gloves

○	Standard configuration
▽	Leading-edge gloves
□	Trailing-edge extensions
◇	Leading-edge gloves and
	trailing-edge extensions

C_L

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C_D α, deg C_m

(b) Natural transition.

Figure 48.- Concluded.

Standard configuration
Four afterbodies 4
Leading-edge gloves and
four afterbodies 4
Four afterbodies 4 and
trailing-edge extensions
Leading-edge gloves, four
afterbodies 4, and
trailing-edge extensions

○   Standard configuration

△   Four afterbodies 4

▽   Leading-edge gloves and four afterbodies 4

□   Four afterbodies 4 and trailing-edge extensions

◇   Leading-edge gloves, four afterbodies 4, and
      trailing-edge extensions

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C_L

C_D α, deg C_m

(a) Fixed transition.

Figure 49.- Aerodynamic characteristics with afterbodies 4 alone and with chord extensions. $\delta_f = 0°$; cowl and
intercooler flaps closed; $R \approx 2,600,000$; propellers off.

Standard configuration
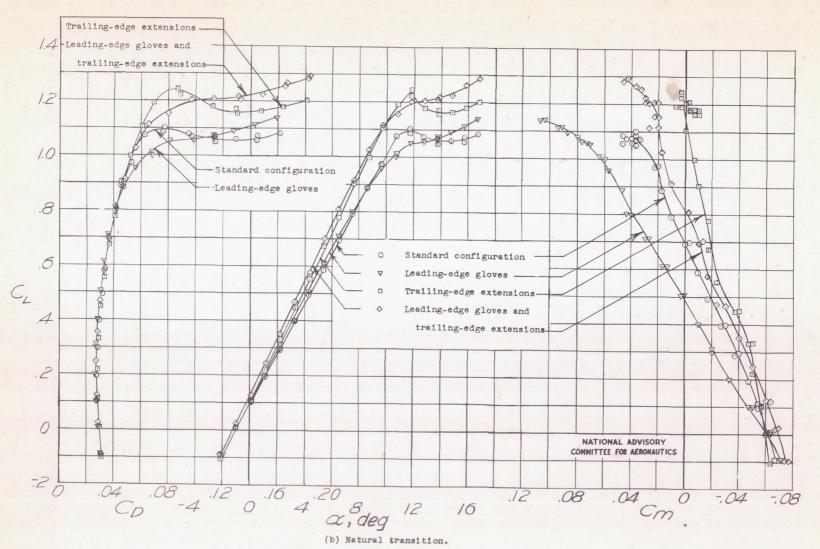
Four afterbodies 4

Leading-edge gloves and four afterbodies 4

Four afterbodies 4 and trailing-edge extensions

Leading-edge gloves, four afterbodies 4, and

trailing-edge extensions

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(b) Natural transition.

Figure 49.- Concluded.

Four afterbodies 5 and
trailing-edge extensions
Leading-edge gloves, four
afterbodies 5, and
trailing-edge extensions

Standard configuration
Four afterbodies 5
Leading-edge gloves and
four afterbodies 5

○   Standard configuration
△   Four afterbodies 5
▽   Leading-edge gloves and four afterbodies 5
☐   Four afterbodies 5 and trailing-edge extensions
◇   Leading-edge gloves, four afterbodies 5, and
      trailing-edge extensions

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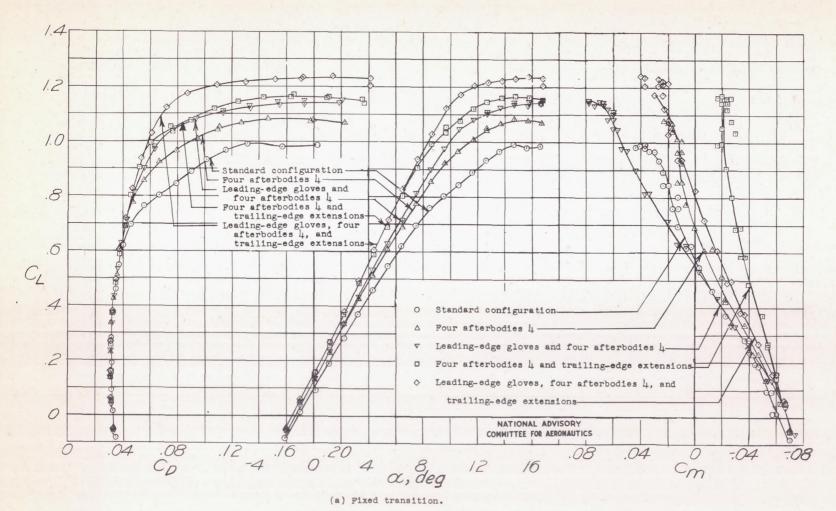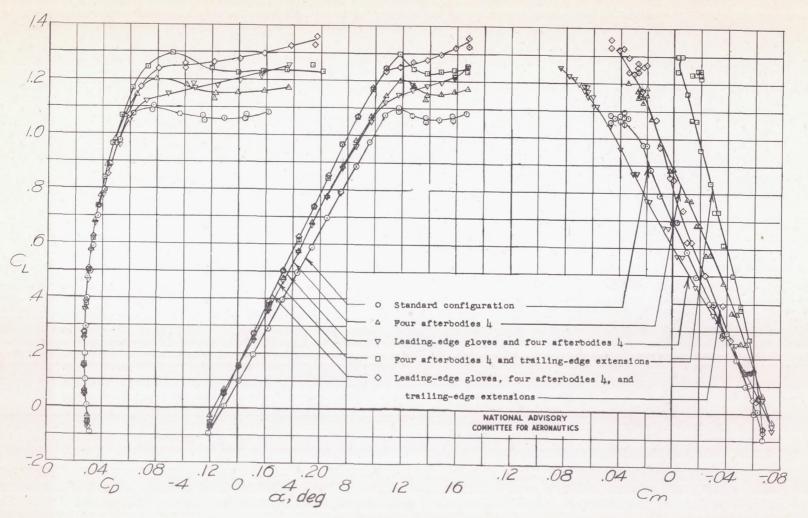
C_L
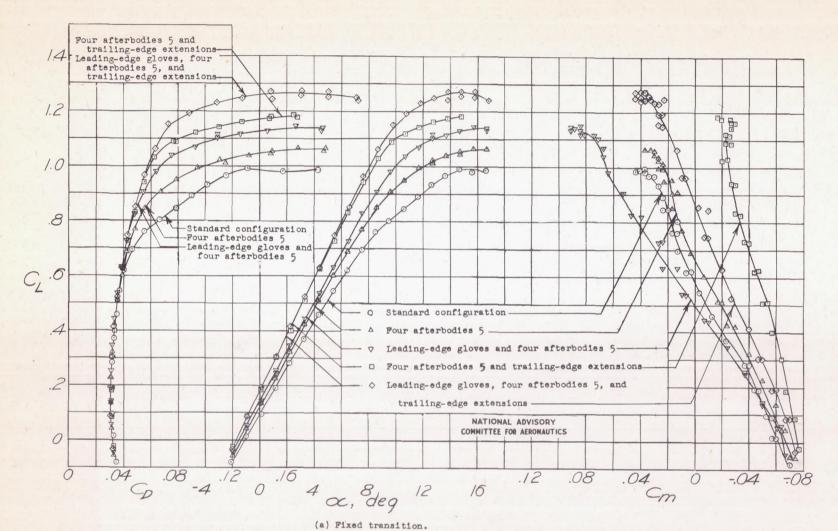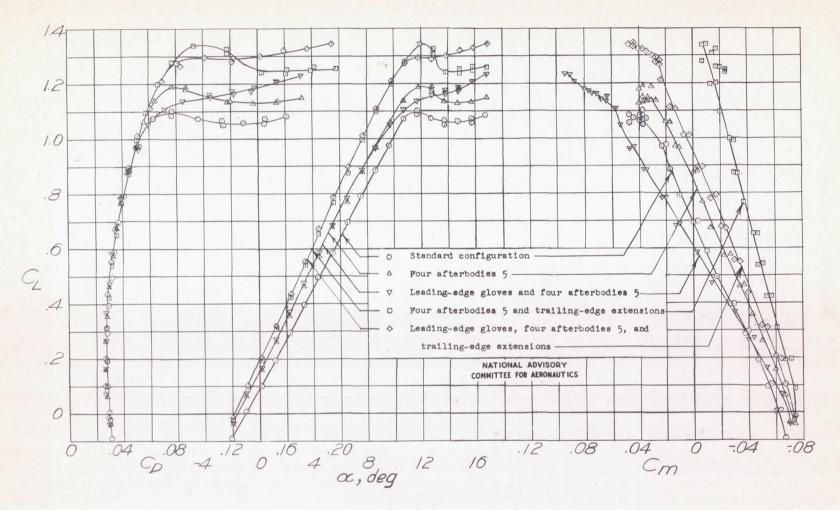
C_D α, deg C_m

(a) Fixed transition.

Figure 50.— Aerodynamic characteristics with afterbodies 5 alone and with chord extensions. $\delta_f = 0°$; cowl and intercooler flaps closed; $R \approx 2,600,000$; propellers off.

Standard configuration

Four afterbodies 5

Leading-edge gloves and four afterbodies 5

Four afterbodies 5 and trailing-edge extensions

Leading-edge gloves, four afterbodies 5, and

trailing-edge extensions

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(b) Natural transition.

Figure 50 .- Concluded.

Standard configuration,
cowl and intercooler
flaps closed

Standard configuration,
cowl and intercooler
flaps open

Four afterbodies 4 and
trailing-edge extensions,
cowl and intercooler
flaps open

Inboard afterbodies 5 and
trailing-edge extensions,
cowl and intercooler
flaps open

O Standard configuration,
   cowl and intercooler
   flaps closed

◇ Standard configuration,
   cowl and intercooler
   flaps open

△ Four afterbodies 4 and
   trailing-edge extensions,
   cowl and intercooler
   flaps open

□ Inboard afterbodies 5 and
   trailing-edge extensions,
   cowl and intercooler
   flaps open

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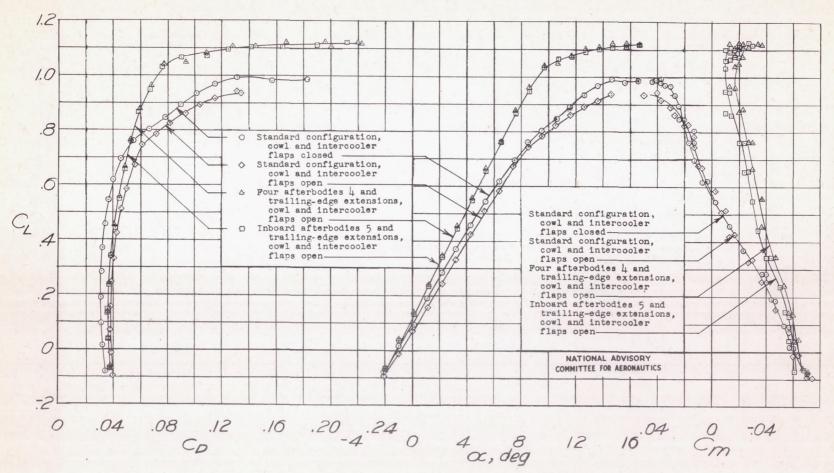COMMITTEE FOR AERONAUTICS

C_L

C_D

α, deg

C_m

Figure 51.- Aerodynamic characteristics with cowl and intercooler flaps open for standard and modified models.

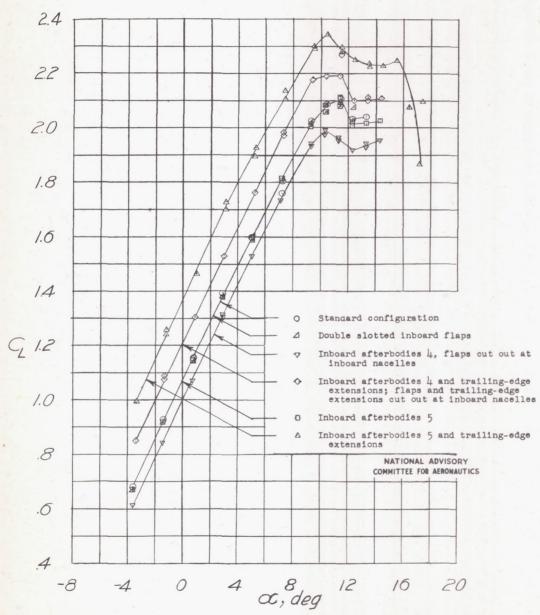$\delta_f = 0°$; fixed transition; $R \approx 2,600,000$; propellers off.
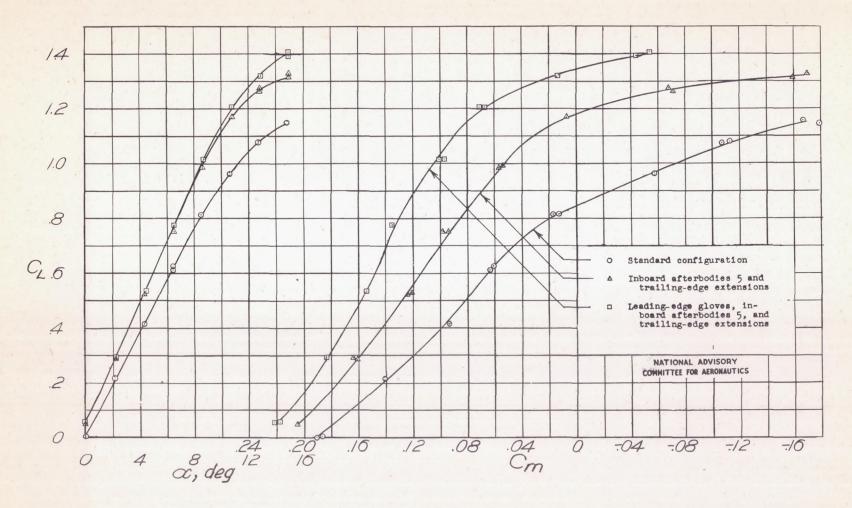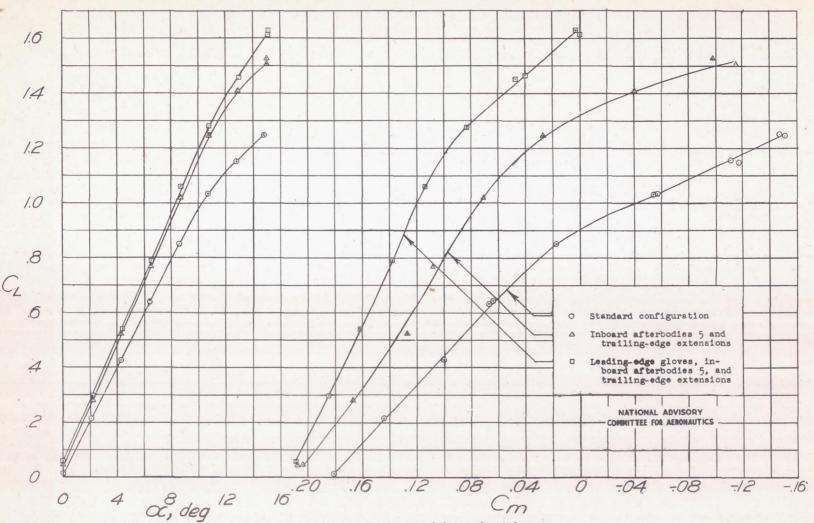
Fig. 51

Figure 52.- Lift characteristics with wing flaps deflected for standard and modified models. $\delta_f = 40^\circ$; cowl and intercooler flaps closed; fixed transition; $R \approx 2,600,000$; propellers off.

Standard configuration

Inboard afterbodies 5 and
trailing-edge extensions

Leading-edge gloves, in-
board afterbodies 5, and
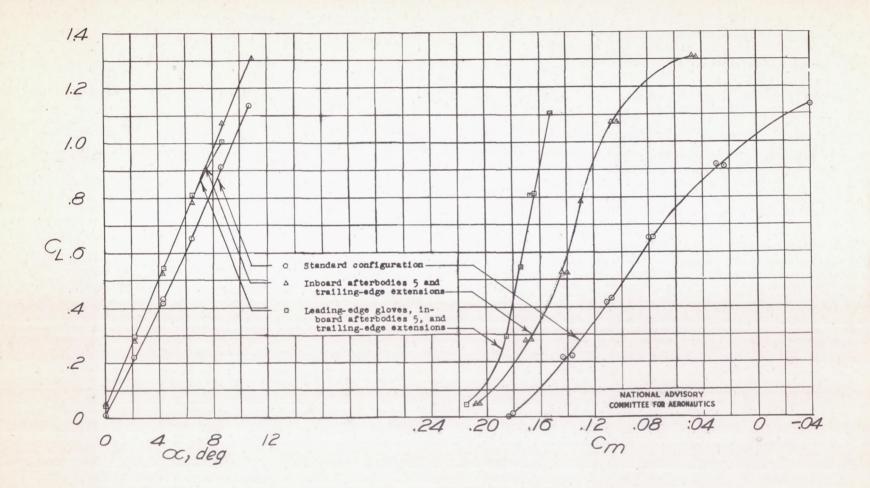trailing-edge extensions

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(a) $T_c = 0$.

Figure 53.- Effect of modifications on pitching moment and lift. $\delta_f = 0^o$;
cowl and intercooler flaps closed; horizontal tail on; transition fixed;
$R \approx 2,600,000$.

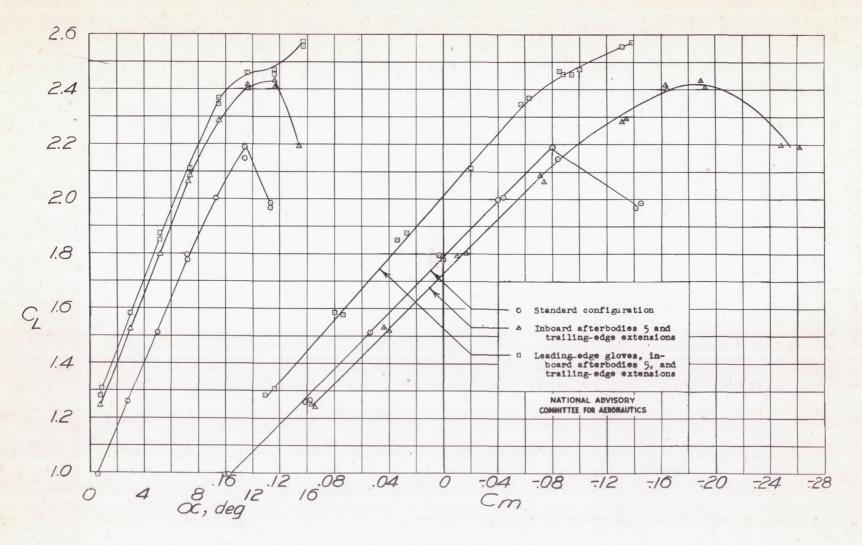(b) Propellers operating at 0.4 normal rated power.

Figure 53.- Continued.

Standard configuration

Inboard afterbodies 5 and trailing-edge extensions

Leading-edge gloves, inboard afterbodies 5, and trailing-edge extensions

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Standard configuration

Inboard afterbodies 5 and
trailing-edge extensions

Leading-edge gloves, in-
board afterbodies 5, and
trailing-edge extensions

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(c) Normal rated power.

Figure 53.- Concluded.

C_L

.16   .12   .08   .04   0   -.04   -.08   -.12   -.16   -.20   -.24   -.28

0   4   8   12   16

α, deg Cm

○   Standard configuration

△   Inboard afterbodies 5 and trailing-edge extensions

□   Leading-edge gloves, inboard afterbodies 5, and trailing-edge extensions

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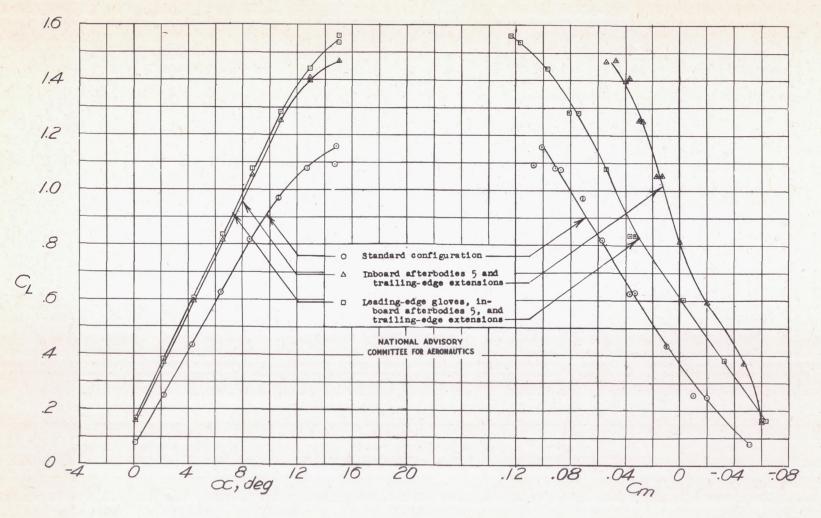COMMITTEE FOR AERONAUTICS

(a) $T_c = 0$.

Figure 54.- Effect of modifications on pitching moment and lift. $\delta_f = 40°$; cowl and intercooler flaps closed; horizontal tail on; transition fixed; $R \approx 2,600,000$.

Legend:
○ Standard configuration
△ Inboard afterbodies 5 and trailing-edge extensions
□ Leading-edge gloves, inboard afterbodies 5, and trailing-edge extensions

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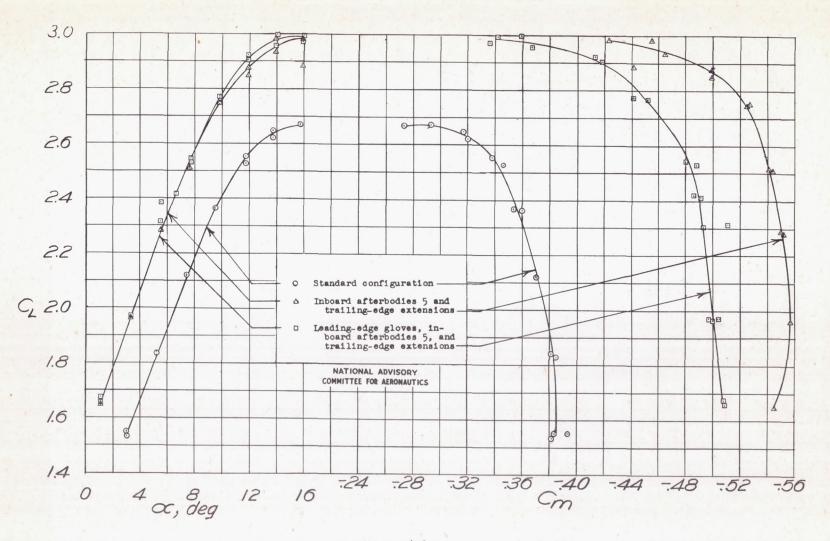
(b) Propellers operating at 0.4 normal rated power.

Figure 54.- Concluded.

Standard configuration

Inboard afterbodies 5 and
trailing-edge extensions

Leading-edge gloves, in-
board afterbodies 5, and
trailing-edge extensions

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(a) $\delta_f = 0^\circ$.

Figure 55.- Effect of modifications on pitching moment and lift. Propellers
operating at 0.4 normal rated power; cowl and intercooler flaps closed;
horizontal tail off; transition fixed; $R \approx 2,600,000$.

Legend:
○ Standard configuration
△ Inboard afterbodies 5 and trailing-edge extensions
□ Leading-edge gloves, inboard afterbodies 5, and trailing-edge extensions

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(b) $\delta_f = 40°$

Figure 55 .- Concluded.